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THE WATER SUPPLY OF SAN FRANCISCO, CAL.

— BY —

C. E. GRUNSKY,

Member of the Technical Society of the Pacific Coast.

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THE WATER SUPPLY OF SAN FRANCISCO, CAL.

By C. E. Grunsky, Member of the Technical Society of the Pacific Coast.

[Read before the Society, August 28, 1908.]

Very early in his connection with the affairs of San Francisco, the writer reached the conclusion that the water works of the city should be municipally owned and that the water works as now in service should form the nucleus of the municipally owned system. Without reviewing the entire water supply question, a few remarks on this phase of San Francisco's water supply problems may be acceptable to the society and may also be of some service to the municipality.

It must be remembered, in the first place, that under the constitution of the state of California it is made the duty of the board of supervisors of the city and county of San Francisco to fix water rates, that is to say, to fix the maximum permissible rates, which are to remain in force for one year and no longer. These rates, according to law, as interpreted by the courts, must be such that they will yield a reasonable return on the value of the properties in actual use. No one has yet laid down a rule, acceptable to both municipality and water company, that can be followed in the determination of the value which should be made the basis of the rate fixing. There is great divergence of opinion as to the items that should be included in a valuation and as to the weight that should be given to different methods of valuation. The boards of supervisors have at times been under suspicion of favoring the water company by fixing rates high; at other times the rates established have been so unsatisfactory to the water company that the courts have been resorted to for relief. The annual recurrence of proceedings for fixing rates is a great embarrassment to any public service corporation. It makes the profits of the business more or less uncertain, particularly as injustice may result from ignorance, or prejudice, or from failure of the legislator to appreciate the high moral obligation of being just to the public service corporation as well as to the people. It is not surprising under this system of fixing rates annually that the public service corporation should have been suspected at times of pernicious political activity, or of attempts to bribe public officials.

It would be better if rates subject to review by the courts were fixed for longer periods than one year. Five years would seem a reasonable time for which to assure an income that will encourage the maintenance of good service. In every case of rate fixing full consideration should be given to the facts that called the public service corporation into being, it being generally true that the municipality was in need of the service rendered and was not ready to undertake the construction of municipal works, but was dependent upon private enterprises, which often involved unusual business hazard. This situation is very different from that occasionally presented of a rival concern, duplicating established works, perhaps forcing a combination, but at any rate being in the field only because the prospect of a profit was good.

Under the law as it stands the water company is slow to expand its works. New sources of supply are added only under the compulsion of dire necessity, and sources of water of doubtful reliability are continued in service as long as the municipality will tolerate them. The present status in San Francisco cannot be maintained indefinitely. Either assurance must be given to the water company that it may continue to do business on a fair basis or the city must acquire water works. The first steps on the latter course have already been taken; the supervisors have declared their intention to acquire water works and have asked for propositions to sell established works to the city.

The City Engineer's Presentation of the Problem in Successive Reports.

As city engineer from 1900 to 1904, it was the duty of the writer to investigate the sources of water from which San Francisco might be adequately supplied. Section 1 of Article 12 of the charter of the city and county of San Francisco provides:

"Within one year from the date upon which this charter shall go into effect, and at least every two years thereafter until the object expressed in this provision shall have been fully attained, the supervisors must procure through the city engineer plans and estimates of the actual cost of the original construction and completion by the city and county of water works . . . and such other public utilities as the supervisors or the people by petition to the board may designate."

Acting under instructions of the board of supervisors and of the board of public works a progress report was submitted by the writer on the water supply investigation under date of August 12, 1901. (Municipal Reports of San Francisco, 1900–1901.)

The following extracts from that report relate to the possibility of making the works of the Spring Valley Water Company a part of any municipally owned water works.

"The combination of some new project having its source of supply in the Sierra Nevada Mountains, with the established system, is a possibility which may ultimately come up for consideration, because the most available nearby storage is already utilized. The Spring Valley Water Works has occupied the most available sites for receiving and service reservoirs, and has an established distributing system and an established business.

"There is no reason why these advantages should not be recognized and why the city should not avail itself thereof, if suitable financial arrangements [terms] can be made [agreed upon].

"For the present, however, as a basis for a cost estimate of water works, it is necessary to proceed on the assumption that a new and independent system is required, and the various projects are considered primarily from this standpoint. Should a combination with the established system be found advisable, then the main alteration will relate to conduit capacity, as it would, in such event, not be necessary to at once put into service two pipe lines, each with a capacity of 30 000 000 gal. per day — a single pipe line would suffice. The pipe line would not terminate in San Francisco, but at Crystal Springs reservoir.

"It is desirable that the combined sources of water supply for this city should be capable of yielding ultimately at least 120 000 000 gal. per day, and that any source of supply now to be utilized, or an extension of the established system, should place at least 60,000 000 gal. of water per day at the disposal of the city and that the capacity of water works should be such as to deliver this amount of water to the city at the outset. Any new source to be combined with the established system should be capable of yielding at least 30 000 000 gal. per day and a possible expansion to 90 000 000 gal. is desirable.

"Under an operation of the Spring Valley Water Works, in conjunction with a Sierra supply, a better water than now furnished is to be anticipated, because the peninsula reservoirs could be kept full and ill-effects of low-water stages with exposed flat marginal areas would be minimized. . . .

"Water works now acquired or constructed by the municipality should serve the city for all time. They should be such that other works with Sierra Nevada sources of supply can, whenever required, be combined with them."

On July 28, 1902, a final report was submitted by me as city engineer on the Tuolumne River project for supplying water to San Francisco. (Municipal Reports of San Francisco, 1903-1904.) The following quotations are from that report.

"This project is submitted in compliance with directions of the board of public works as authorized by the board of

supervisors under charter requirements. It is not to be inferred, however, that the city engineer desires to recommend, in submitting this report and a cost estimate, the original construction of an entirely independent water works system as here outlined.

"It must be manifest that such procedure would render valueless certain properties of the Spring Valley Water Works now used in supplying water to this city. As some of these properties can be incorporated in the proposed system to advantage, no other conclusion can be reached than that the interests of the city and of the Spring Valley Water Works are mutual — to have the established works in part, at least, retained in service, and to have the new works supplement that part of the Spring Valley Water Works system which can be thus retained in use. This fact should not be lost sight of in negotiating for the established works as required by law.

"Enough has been said to show that there is no more available source of supply of first quality water with which to supplement the supply of the Spring Valley Water Works than that herein reported upon. Treated from the standpoint of a supplemental supply, however, it should be remembered that the delivery of surplus water would then be into Crystal Springs reservoir instead of into a new reservoir at Belmont, and that a single pipe line with a capacity of 30 000 000 gal. per day would fully meet all immediate requirements. . . .

"The city distributing system would come into use without modification, except the placing of larger mains in some sections of the city to insure the best possible fire protection and the construction of new reservoirs and tanks and an improvement of the pumping facilities. It is thought that an expenditure of $1 000 000 in betterments of this kind would be at once justified if the Spring Valley Water Works' supply were augmented by a supply from the Sierra Nevada Mountains, and that about $500 000 would cover the cost of the receiving reservoir at the House of Refuge lot, and its service mains.

"The appraisements made from time to time of the value of the Spring Valley Water Works properties, as a basis for fixing water rates, may serve as a preliminary guide in determining the financial aspect of such a combination system.

"Should it be carried out, then the conditions under which the nearby sources serve can be materially improved. The Crystal Springs reservoir and Lake Merced can be filled with Sierra Nevada water and kept full. The former will be drawn upon only to the extent of the annual yield or even less, so that less variation in quality of water than at present is to be anticipated."

The availability of various sources of water for use in San Francisco after discussion by the writer as city engineer in the reports already referred to of August 12, 1901, and of July 28, 1902, was further dealt with in a report dated November 24,

1902. (Municipal Reports of San Francisco, 1903–1904.) Extracts from this report relating to the Spring Valley Water Works follow.

"The essential facts relating to the Spring Valley Water Works system and its sources of supply have already been presented in the progress report of 1901. These established works cannot be ignored when an earnest move is made toward the acquisition by the city of municipal water works. In their entirety they are comparable with the other projects that are or have been under consideration.

"No proposal has been submitted for a sale of the properties of the Spring Valley Water Works or any portion thereof to the city, and no definite project for the acquisition thereof has yet been formulated. Such a project would necessarily differ materially in some of the most important features of water works from the other projects under discussion. In the first place, the works have the advantage of being already constructed and in actual use. They are supplying between 25 000 000 and 30 000 000 gal. of water per day. Their distributing system, which, with its 400 miles of pipe, reaches every important establishment in the city, and from which some 50 000 private services are supplied, will either come into use with some other project, or it must be practically duplicated in case that it be not made a part of the municipal system. Other portions of their works, even though their water sources be ignored, would still be valuable to safeguard the supply from distant sources. In the second place the sources of water utilized by the Spring Valley Water Works are near at home. The advantage of short lines of conduits is in a large measure, however, offset by the disadvantage of widely scattered works and the necessity for taking unusual precautions to prevent the pollution of the waters. In the third place, these works can be acquired only after negotiation with present owners and agreement upon a price.

. . . . . .

"It appears from what has been said in the foregoing pages and the earlier reports herein referred to that the Spring Valley Water Works system, to the extent of its capacity, ranks first in the reliability of service; that the Tuolumne River project ranks highest in the quality and quantity of water; that in the matter of first cost to the city, the advantage should be in favor of the Spring Valley system (a sale at a fair price is to be assumed).

"It is to be added that in the matter of operation it remains uncertain which system, the Tuolumne River project or the Spring Valley Water Works, would have the advantage — the probability being in favor of the newer system.

"Under a combination of these two projects, only a part of the Spring Valley Water Works' properties would be required. Whether such combination would prove of advantage to the city cannot well be determined in advance of an agreement upon the

price at which the necessary parts of the established system could be acquired."

On the occasion of a farewell banquet tendered by citizens of San Francisco to the writer upon his appointment as a member of the Panama Canal Commission, he found opportunity to say in reference to the water supply of San Francisco:

"San Francisco is the only city of its size in the United States which does not own its water works.

"There is no question in my mind that water works municipally owned would be well managed, would enable a reduction of water rates for the same service rendered and would enable the city to provide for its inhabitants the best and purest water obtainable from any source.

"Half a century is but a short time in the life of a city. Looking into the future fifty years, we see in place of our present city a magnificent metropolis — the upper end of our peninsula from bay to ocean densely covered with buildings; the population increased to over one million; Oakland, Berkeley and Alameda clamoring to become a part of San Francisco, if they have not already been made a part thereof; and for this city of the future it is now time to plan the water works, nothing being so essential to the health and comfort of the inhabitants as an abundant supply of pure water.

"In thus looking ahead, it has become apparent to those who have carefully studied the matter that the ultimate source of supply for our water must be in the high Sierra Nevada Mountains. The steps that have been taken to secure water from these mountains is known to all and need not be repeated. Legislation is now pending in Congress which may give to San Francisco the source of supply which comes nearest to being ideal. Whether the project for municipal water works based upon such a source must be carried out at once as an independent project or whether the same must be combined with the present system is the question which will, in the near future, confront the people of this city; but whatever the source of the water, the water works should be municipally owned. The sooner this is brought about the better for the city. Until then the annual trouble and annoyance of fixing the rates to be charged by private corporations will continue, and ill feeling will be engendered between municipal authorities and the officers of the water corporation, and the service cannot be expected to be such as would be rendered under municipal ownership.

"No private corporation can ever do as well for the public, as long as its efforts are being continually discredited and its income is uncertain, as could be done by a competent water department of the municipality. Of all questions relating to municipal ownership of public utilities, none is of such importance, none so urgently pressing, as that of the ownership of the water works. The obstacles which at the present time seem to

be in the way of securing from the federal authorities the reservoir rights of way in a forest reservation, as asked for, are probably not as great as appears on the surface. The main opposition comes apparently from the irrigation districts which are dependent upon water from the Tuolumne River. These districts are not now in a position financially to increase the flow of water into their canals by means of storage in the high mountains. They look forward, however, to the time when the increasing areas under cultivation, the increasing demand for water which will be necessary for irrigation, will make storage in the high mountains desirable. These districts at the present time look with alarm upon the taking of any water from the Tuolumne River for the benefit of San Francisco. As a matter of fact, however, the water to be taken by San Francisco is not water which would be of any benefit to the districts, being only a small portion of the waste flood waters of the river which now flow unused to the sea.

"San Francisco would, then, be depriving the districts of nothing except merely of the opportunity to store water for their own use when the time for such storage shall have come, in those two particular reservoir sites for which San Francisco has made application. To these reservoir sites San Francisco has as good a right as any person or any other section of the state. San Francisco has made the first application for them and San Francisco must take every step necessary from time to time to protect her rights and to be allowed to use these storage sites for the impounding of water if such storage be ever permitted in the forest reservation. But the flood waters impounded when the storage works shall have been completed will for many years — from a quarter to half a century — be far in excess of the amount actually required to supply the needs of San Francisco and her inhabitants.

"There will be a large surplus of water in the reservoirs, and this surplus can be liberated at times when it will be of greatest benefit to the lands in San Joaquin valley upon both sides of Tuolumne River requiring irrigation. It is to be anticipated that in these irrigated districts the soils will gradually become saturated with water, and after a number of years the water required per acre irrigated will gradually decrease. At the same time the districts will be decreasing their bonded indebtedness and the time will come when they will feel financially able to carry out storage works of their own, and then they, like San Francisco, will be compelled to apply for the privilege of utilizing storage sites in the forest reservation.

"When this situation is thoroughly understood by the irrigation districts, instead of opposition, San Francisco should receive their help.

"The more thoroughly the available sources of water supply are investigated, the more it will become apparent that the solution of the water question lies along the lines that have been indicated and that the time has come for determining to what

extent the established water works are to enter into the ultimate water supply project. I trust that the day may not be far distant when the municipal ownership of water works will be an accomplished fact."

Acquiring Control of the Reservoir Sites on Tuolumne River.

Among the sites for the storage of water in the Sierra Nevada Mountains which have been examined and reported upon by the engineers of the United States Geological Survey are Lake Eleanor and the Hetch Hetchy Valley. Both of these reservoir sites are in the watershed of Tuolumne River. The latter is on the main stream. Writing of this reservoir site in the twenty-first annual report of the Geological Survey, Mr. J. B. Lippincott, of Los Angeles, then the assistant in charge of the hydrographic work of the Survey in California says:

"The valley proper is about three and one-half miles long and of a width varying from one quarter to three quarters of a mile. The rugged granite walls, crowned with domes, towers, spires and battlements, seem to rise almost perpendicularly upon all sides to a height of 2 500 ft. above this beautiful emerald meadow. . . . It was visited in May when the snows on the glacier meadows on the higher altitudes were rapidly melting, and the river was bank full and overflowing the lower part of the valley. The water is here dammed up, owing to the narrow outlet between high mountains of granite rock."

The Tuolumne River, as a source of water for San Francisco, with Lake Eleanor and Hetch Hetchy Valley as reservoir sites, was investigated preliminarily and reported upon by the city engineer in 1900. In January, 1901, the first step was taken toward acquiring reservoir rights-of-way in the watershed of Tuolumne River. The following extracts are from a communication addressed by the writer, at that time city engineer, to the board of public works, under date of January 23, 1901.

"The water supply investigation has been advanced sufficiently to justify the conclusion that San Francisco will ultimately be in need of a source of water from the Sierra Nevada Mountains either with or without the utilization of the established works and nearer sources. Preliminary examinations demonstrate the practicability of bringing in a supply from such a source.

"Under these circumstances the acquiring of the necessary water rights and storage facilities should not be overlooked. They should be secured as opportunity offers to the end that when the time comes works may be established adequate to meet the future needs of this city.

"To prevent certain privileges and rights that may be of vital importance from falling into the hands of speculators, private individuals or private corporations adverse to the interests of this city, and as the regulations of the Department of the Interior permit the filing of applications and the setting apart to individuals or corporations of reservoir sites in the public domain, application should at once be made to the Secretary of the Interior to set apart for the use of this city the Hetch Hetchy Valley and Lake Eleanor reservoir sites."

Applications for the reservoir rights-of-way here suggested were necessary because, although in each case some of the required land was in private ownership, both of the dam sites are on the public domain and some government land would be flooded by the construction of dams. The right to use land for the reservoirs and the right to erect dams could be granted only by the Secretary of the Interior.

The first steps that were taken in this matter could not be made public without endangering the success of a movement for Tuolumne River water. Under joint action of the board of public works and the mayor, James D. Phelan, the city engineer was authorized to include in the surveys on the Tuolumne River such right-of-way descriptions at Lake Eleanor and in Hetch Hetchy Valley as were requisite in making formal application for the reservoir sites.

It was found upon inquiry that there was no precedent for an application by a municipality for a right-of-way in a national forest reservation. The advice received in the matter was that it would be safer to let an individual make the application and to let rights acquired thereunder be subsequently assigned to the city. This procedure had the advantage, too, that it obviated the necessity for publishing the intent of the city to apply for rights that were apparently to be had for the asking. Interference with speculative interests was thereby in all probability avoided. Mayor Phelan was obviously the proper person to make the application, but he had to do it as a private citizen. Subsequently, he made a complete transfer to San Francisco of all rights that might be acquired under his application. What Mayor Phelan did in this matter is what was asked of him by the city engineer and by the members of the board of public works. It is no more and no less than would have been expected of any other mayor.

The surveys were so far advanced that in October, 1901, an application could be made for the two reservoir sites, and the necessary papers were filed in the Stockton land office. More

than a year elapsed before word was received from Washington that the application for both rights-of-way had been rejected on the ground that the law made it obligatory upon the Secretary of the Interior to preserve the natural wonders in national parks. The city was advised by the Secretary of the Interior that congressional action would be necessary to make the utilization of the two sites possible. The usual opportunity for requesting a review of the decision was, however, given to the city. A review was granted and the city, through its city attorney and its city engineer, presented its case to the Secretary of the Interior in March and April, 1903.

Until this time there had been no opposition manifest to the acquisition of water rights and reservoir sites by the city, although there had been no attempt to conceal the city's purpose after the application for reservoir rights-of-way had been filed.

In July, 1901, notices of claims to water had been posted in Tuolumne County and filed for record in the name of Mr. Phelan; in October, 1901, the filing in the land office was made and under date of July 28, 1902, the city engineer submitted a report on the Tuolumne River water supply project. In this report full explanation of the right-of-way applications was made. The matter had also received more or less attention by the newspapers.

At the hearing in Washington it developed, however, that the Spring Valley Water Works were represented by their manager in opposition to the city's application. Representation was made by him, not only that the city did not need to go to the Sierra Nevada for water, but that the water of the Tuolumne River could not be used by San Francisco without detriment to a large farming community which would ultimately require all the water of the river. At this hearing it also became apparent that the two irrigation districts had suddenly been awakened to a belief that the proposed water storage by San Francisco was a serious menace to the prosperity of the districts. So recent was this awakening that it was manifested by telegraphic communications from each of the two attorneys of the districts to the Secretary of the Interior.

It developed at this hearing, too, that the long time which had elapsed since the city filed its application had given private parties the opportunity to make surveys and file or offer for filing a rival application for the Lake Eleanor reservoir site. Mr. William Hammond Hall appeared as the representative of persons whom he would not name, and made the point that the

city had forfeited rights to priority in the matter of Lake Eleanor because it was disclosed by the cost estimate and general plans of the proposed works for utilization of Tuolumne River water that Lake Eleanor was not to be included as a part of the Tuolumne River project. The city needs both sites and no other conclusion is possible from a reading of the city engineer's reports than that the only question was the order in which they should be brought into use. The fact that a Lake Eleanor dam was not projected for immediate construction is no evidence that the same was eliminated from consideration as an essential ultimate requirement. The immediate construction of both reservoirs was not recommended for financial reasons.

The review of the Secretary of the Interior's decision did not lead to any modification thereof. The first conclusion that he could not grant the required privilege to San Francisco without legislation was confirmed. But the matter was not allowed to drop. The President and Congress were memorialized, and bills were introduced providing for a grant to San Francisco of the necessary lands at both reservoir sites.

The situation at this time is clearly set forth in the memorial adopted by the board of supervisors, on January 4, 1904, which is as follows:

"The board of supervisors of the city and county of San Francisco respectfully presents the following memorial to the President and Congress of the United States:

"*Whereas*, Under the provisions of the constitution of the state of California, 'the use of all water now appropriated, or that may hereafter be appropriated, for sale, rental or distribution, is . . . declared to be a public use, and subject to the regulation and control of the state, in the manner to be prescribed by law'; and the Civil Code of the state, in paragraphs 1410, 1411, 1413 and 1414, declares,—

"'The right to the use of running water flowing in a river or stream, or down a canyon or ravine, may be acquired by appropriation';

"'The appropriation must be for some useful or beneficial purpose, and when the appropriator or his successor in interest ceases to use it for such a purpose the right ceases';

"'The water appropriated may be turned into the channel of another stream and mingled with its water, and then reclaimed; but in reclaiming it, the water appropriated by another must not be diminished;'

"'As between appropriators, the one first in time is the first in right';

"*Whereas*, It has become manifest that the water supply of this city must sooner or later be increased by the addition of a

supply from the Sierra Nevada Mountains, and the securing of this supply should not be delayed;

"*Whereas*, The city and county of San Francisco proposes to appropriate for the use of its inhabitants, as authorized by law, water of the Tuolumne River, it having been found, as the result of the exhaustive investigations by the board of public works of San Francisco that this river is the best and most available source of supply to meet the immediate and future requirements of this large, important and rapidly growing city;

"*Whereas*, This appropriation of water is to be made without interference with vested rights, and this can be accomplished only by the storage of large quantities of the flood flow of the river and its tributaries;

"*Whereas*, The sites for the storage of the waste, storm or extra-seasonal waters of the Tuolumne River are located within a forest reservation generally referred to as a national park, and the Secretary of the Interior being authorized and empowered by the act of Congress, approved February 15, 1901, to permit the use of rights-of-way through the public lands, forest and other reservations for such reservoirs used for the supplying of water for domestic, public or any other beneficial uses to the extent of the ground occupied by such reservoirs, applications were duly made for two reservoir sites, one on the Tuolumne River, at the point known as Hetch Hetchy Valley, and one at Lake Eleanor;

"*Whereas*, These applications for reservoir rights-of-way were denied by the Secretary of the Interior, who points out that, as viewed by the Department of the Interior, 'the application is confronted by legal embarrassments which appear to be surmountable only by the exercise of the legislative power of the government';

"*Whereas*, The specific reason of the rejection of these applications is in part stated by the honorable Secretary of the Interior as follows: 'The act of October 1, 1890, makes it obligatory upon the Secretary of the Interior to preserve and retain the "natural curiosities and wonders" in the park in their "natural condition." This provision of the act which establishes the park remains in full force, not having been repealed or modified by the act under which this application is made nor by any other legislation.

"'It is contended that the appropriation of Lake Eleanor and Hetch Hetchy Valley for great reservoirs for the proposed storage of water would enhance rather than detract from their natural beauty, but this is not material in view of the law which commands the Secretary of the Interior to preserve and retain them in their natural condition if they are "natural curiosities."

"'There may be a difference of opinion as to what natural objects may be justly considered as being within the meaning of this provision of the law, but there can be no doubt about the duty of the Secretary of the Interior if, in his judgment, they are such natural curiosities or natural wonders so contemplated by the act';

"*Whereas*, Both of these sites have been recognized by the Department of the Interior as desirable and available for the storage of the flood flow of mountain streams, as demonstrated by the reports of the United States Geological Survey, in which these reservoir sites are repeatedly referred to. A plat of the Hetch Hetchy Valley was submitted to the Secretary of the Interior by the United States Geological Survey and its reservation from entry or settlement according to law was asked for under date of February 27, 1891. [See opening statement and page 36 of Part II of the Twelfth Annual Report of the United States Geological Survey.] A further report upon the availability of this reservoir site, with a study of the works necessary at the dam-site, are contained in the Twenty-first Annual Report of the United States Geological Survey, pages 450 to 465, in which, on page 459, it is stated: 'Another purpose which this dam and reservoir might be made to serve would be to furnish the city of San Francisco with an unfailing supply of pure water. Without entering into details, it will suffice to say that the dam and reservoir as proposed would insure a supply in the driest years of 250 gallons per diem per capita for 1 000 000 people.' Lake Eleanor and the segregation of its lands for reservoir purposes is referred to in Part II of the Eleventh Annual Report of the United States Geological Survey, page 157, on the plate between pages 160 and 161, and on page 167; also in the Thirteenth Annual Report, Part III, page 402;

"*Whereas*, It is not conceivable that the maintenance of a forest reservation with an area of about 1 500 square miles is to interfere to any material extent with the development of water for useful purposes, particularly when such utilization introduces into the park a new lake about 2 square miles in area and enlarges a second from less than one half to nearly two square miles, enhancing the natural beauties of the park instead of detracting from them;

"*Whereas*, Neither of the two sites in question is now accessible by wagon road, and will never be visited by any considerable number of persons except in the months, July, August and September, when the stage of water in the lakes will be high;

"*Whereas*, The use to which the water is to be put is the highest possible beneficial use;

"*Therefore*, this board memorializes the President and Congress of the United States to pass such laws as may be necessary to grant to the city and county of San Francisco the right to use the reservoir sites heretofore applied for."

In addition to this a direct appeal was made to the President for the city by Mr. Marsden Manson, now city engineer, and resulted in the obtaining of an opinion from the Attorney-General of the United States to the effect that the power to grant rights-of-way as applied for by San Francisco was vested in the Secretary of the Interior. The bills before Congress were not, therefore, pressed.

In the meanwhile Mr. James R. Garfield succeeded Mr. E. A. Hitchcock as Secretary of the Interior, and in the light of the Attorney-General's opinion a request was presented to him to have the matter reopened. This request was granted and after many conferences and long deliberations San Francisco has been granted the rights asked for, subject, however, to such control on the part of the United States government as will protect the prior rights of the irrigation districts.

In order that the situation may be clearly understood, a brief description of the works now in use and of the proposed Tuolumne River project is here given.

Water Works hitherto in Use. Sources Developed.

Practically the entire city is now supplied with water by the Spring Valley Water Company. The service of the Visitacion Valley Water Company, of the John Center Works which were of such great service in checking the southerly advance of the great fire in 1906, and of a few other minor concerns, is so small that it need not be further considered in this discussion.

It is noteworthy, however, that for various purposes water in large quantity is drawn from the bay and the ocean, thereby decreasing measurably the demand on the established service. Various concerns use salt water for condensing. The Olympic Salt Water Company supplies some water for this purpose and some for bathing, drawing its supply from the Pacific Ocean. The power stations of the United Railways are all supplied with salt water drawn from the bay for cooling purposes. The city is now about to construct a high-pressure fire protection system which will draw water from wells and from the bay.

For use in Golden Gate Park water is pumped from wells at two points: at a pumping station near H Street and Thirteenth Avenue for general use, and at a point near the ocean by a Dutch windmill for a supply to the chain of lakes and other uses. The Presidio draws water from wells at Mountain Lake.

The fact that a large amount of salt water and locally obtained water will always be used for various purposes; that the climatic conditions, particularly the cool weather and fogs of summer, keep down the water consumption, and the fact that restricted building areas will compel the crowding together of residences and will keep down the area of lawns and gardens — these facts all contribute to make the water requirement of San Francisco relatively small. It can probably, without undue restrictions upon the water consumer, be kept at about 80 gal. per inhabitant.

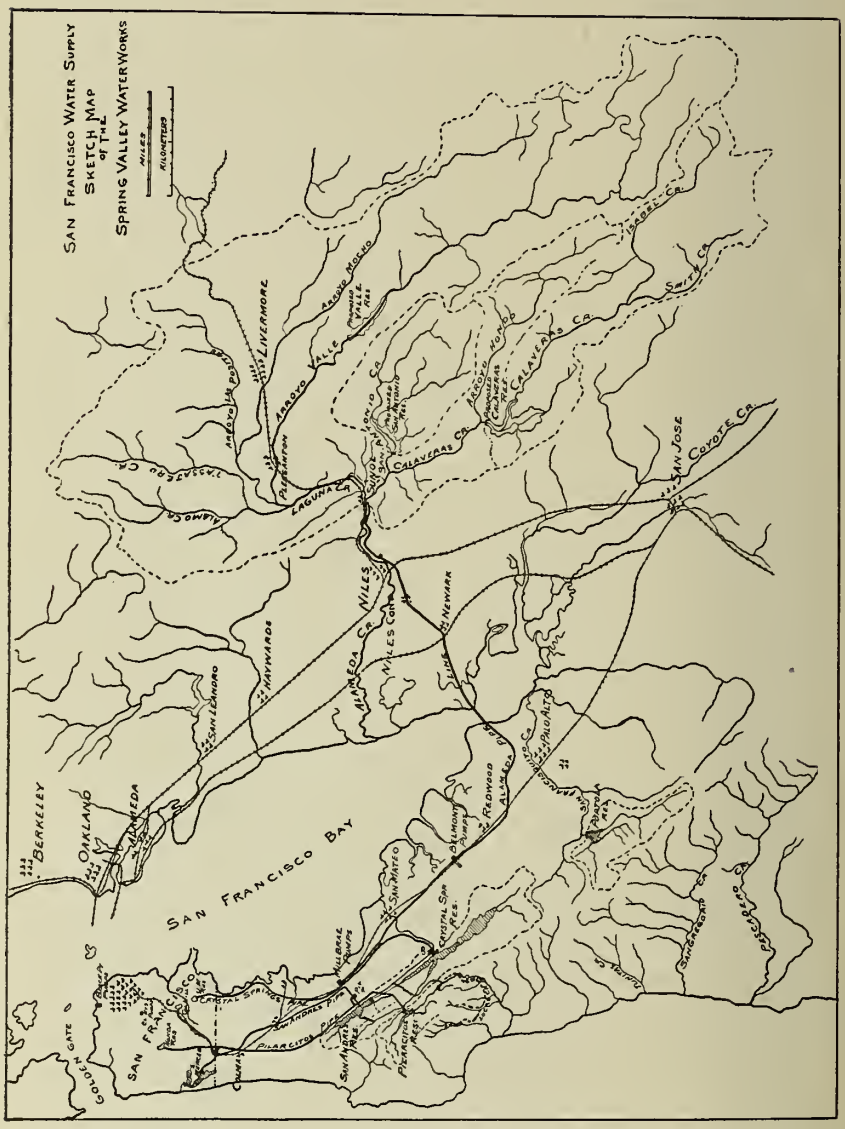
In the early days of San Francisco's history, water for drinking purposes and domestic use was peddled about the streets in water wagons. Fire protection was afforded by fire engines operated by hand and by cisterns which were filled with salt water pumped from the bay.

About 1858 Lobos Creek water was brought into the built-up portion of the city by the San Francisco City Water Works. The flume around Fort Point, at an elevation of about 20 ft. above the ocean, which was in service until 1895, will be remembered in this connection. This source of supply remained in use, therefore, nearly 40 years. Lobos Creek was not finally abandoned, however, as a possible source of water until the year 1901.

The construction of the City Water Company's works, which included a pumping station at Black Point and a reservoir on Russian Hill, was quickly followed by the organization of a rival company. The projector of this rival company was Geo. H. Ensign, who controlled certain water rights deemed to be adequate for the intended purpose. Among the sources that had been or that were being drawn upon was a spring located somewhere on the slopes of Clay Street Hill in a depression then known as Spring Valley. This explains the name adopted by the company. Under date of January 1, 1865, the San Francisco City Water Works sold out to the Spring Valley Water Works, and the latter corporation five years ago sold out to the Spring Valley Water Company.

As the city grew the nearest sources of water were one by one abandoned and new sources farther away from the center of population came into use. As early as 1863 to 1865 the Pilarcitos reservoir was constructed and added to the system. It came into use as a small reservoir formed by a low earth dam, which was submerged and went out of service when the present higher dam was completed in 1869. San Andres reservoir came into use in 1870, and the Upper Crystal Springs or Cañada de Raymundo reservoir, now a part of the Crystal Springs reservoir, about 1878. Merced Lake was added to the water works in 1877 and 1878. The explosion of a boiler wrecked the pumping station at this lake in 1885, and it remained out of use thereafter until 1891, when the present pumping station came into service. Alameda Creek water, the right to which had been acquired in 1875 by the purchase of the Alameda Water Company's properties, was first brought across the bay in 1888. The diversion was then at the Niles dam. Seven years later the point of

GRUNSKY. PLATE I.



diversion was changed to Suñol valley, and the filtration feature was added to this part of the water works system. The amount of water diverted from the creek was materially increased at that time. The construction of the Crystal Springs concrete dam on San Mateo Creek was commenced in 1886, and work on this structure was continued until 1892. Lobos Creek went out of use with the destruction by landslides of the flume around Fort Point in 1895. It was to be again added to the system in 1901, but yielding to the wishes of the city authorities the water company finally abandoned it as a source of supply in the same year.

Pilarcitos reservoir is fed by a creek of the same name which courses down the ocean slope of the Montara spur of the coast range. It is located about 12 miles south of the south boundary of San Francisco. The elevation of the water surface of a full reservoir is 682 ft. above San Francisco city base (this base is about 10 ft. above mean sea level). The reservoir is formed by an earth dam 90 ft. high and 730 ft. long on the crest. Its surface area when full is about 105 acres. The storage capacity of the reservoir is 940 000 000 gal.

Until destroyed by the earthquake of 1906, a wrought-iron pipe, 30 in. in diameter, brought the Pilarcitos water into San Francisco. Since that time the Pilarcitos water is allowed to flow into San Andres reservoir and reaches the city through the San Andres pipe. The watershed tributary to the Pilarcitos reservoir is 3.5 sq. miles, to which, by side hill flume, about 1.4 sq. miles more has been added.

San Andres reservoir is about two miles nearer to San Francisco than the Pilarcitos reservoir. It is located on the bay side of the mountains and at a lower altitude. Its elevation when full is 435.6 ft. above city base and the surface area of the reservoir is 475 acres. This reservoir lies on a small branch of San Mateo Creek and there is tributary to it, naturally, a watershed having an area of 4.1 sq. miles. To this there was added in 1897, by a tunnel known as the Davis Tunnel, an area of 0.9 sq. miles cut-off from San Mateo Creek. The Locks Creek line of flume and pipe, which was in service until about 1899, added run-off waters from 3.4 sq. miles of additional area. Thereafter for several years all of the Locks Creek line above Apanolio Creek was out of service. Now the New Locks Creek line is in the main an interceptor of Pilarcitos water below Pilarcitos dam, including wastage from Pilarcitos reservoir. The area at present made partially tributary to Lake Andres by this conduit includ-

ing 1.5 square miles of San Mateo Creek below the Davis tunnel, may be taken at about 3 sq. miles. The San Andres dam is an earth embankment, lying just on the edge of the fault line on which there was a horizontal movement of about 7 ft. at the time of the earthquake of 1906. The abutment of the dam is cut by the fault. The dam has remained intact and uninjured. The dam is 90 ft. high, and has a crest length of 990 ft. The San Andres reservoir when full holds 5 723 000 000 gal. of water. Waste water, when there is any, flows from this reservoir into the Crystal Springs reservoir. The water from this reservoir flows through a tunnel 2 820 ft. long into a measuring box, then into a screen house, where it is passed through cloth screens. It is thereupon carried in 28 849 ft. of 44-in. wrought iron pipe, 40 185 ft. of 30-in. pipe and 1 400 ft. of 37-in. pipe, the latter across a creek between Baden and Colma, to San Francisco, where delivery is made into the College Hill reservoir.

The Crystal Springs reservoir is the largest of the storage reservoirs on the peninsula. It lies about 4 to 8 miles further from San Francisco than the San Andres reservoir. It is formed by a dam across San Mateo Creek just below the point where the creek receives the waters of the Cañada de Raymundo from the south. The reservoir as it now exists is formed by a massive concrete dam. This was constructed in the years 1887 to 1892. The dam is to be raised 30 ft. at some time in the future. As it now stands it has a height of 146 ft. and the reservoir formed by it has a capacity of about 18 900 000-000 gal. The elevation of the top of the present structure is 280 ft. above city base.

Some years before this dam was constructed, as already stated, there had been constructed the Upper Crystal Springs or Cañada de Raymundo dam. This dam is of earth. On its crest, which is slightly higher than the crest of the Crystal Springs concrete dam, is a road. Upon the completion of this dam in 1878, and for seven years thereafter, the water stored by it was pumped into the San Andres system. But in 1885 the 44-in. Crystal Springs pipe line was completed and water then flowed by gravity from the Cañada de Raymundo reservoir to the University Mound reservoir in San Francisco. The earthquake of 1906 split the dam crosswise, one end of the structure being moved about 8 ft. with reference to the other. At the time of this earthquake, April 18, 1906, the water level on both sides of the dam was the same. There was, therefore, no flow of water through the structure and no damage from this

cause. The dam has been of no importance as a feature of the water works since the construction of the concrete dam.

The Crystal Springs concrete dam is about 600 ft. long on top. It is arched upstream. About 164 000 cu. yd. of concrete were required in its construction and in the construction of a deep cut-off wall across a low gap north of the hill against which the north end of the dam abuts. At the elevation of the present top of the dam the water surface area of the reservoir is about 1 300 acres. The area of the watershed tributary to the Crystal Springs reservoir, not including the area cut off by the Davis tunnel, is about 23.2 square miles. Of this area about 12 square miles were tributary to the Upper Crystal Springs reservoir. The conduit from the Crystal Springs reservoir to San Francisco is a 44-in. wrought-iron pipe. The route followed by this pipe is along the bay shore. It crosses a long stretch of swampy ground near Baden and lies upon hilly and otherwise difficult ground at Sierra Point. One spur of the hills is here pierced by a tunnel 300 ft. long. After crossing Visitacion valley the conduit is again in tunnel 2 145 ft. long. It discharges into University Mound reservoir. The total length of this conduit is 87 066 ft.

Among the works on the peninsula south of San Francisco that are productive of water is the Locks Creek line. Originally this aqueduct included a long conduit skirting the ocean slope of the mountains into which water from a number of small creeks was admitted.

The upper end of the conduit was at Locks Creek. About 1897 the upper part of the works down to Apanolio Creek and in 1901 another section below this creek, went out of service. Since 1901 the lower part of this line as reconstructed has alone been in use. At the head of these works as now in service on Pilarcitos Creek, about a mile below the Pilarcitos reservoir, is a stone dam about 35 ft. high. This dam diverts the flow of Pilarcitos Creek into a flume. To the natural flow of the creek there is here added some water intercepted by a hillside flume, which discharges into the basin above the stone dam. The overflow or waste water from the Pilarcitos reservoir reaches the stone dam and opportunity is thus afforded for turning it into San Andres reservoir. The flume from the stone dam carries the water about three quarters of a mile to a tunnel 3 200 ft. long, which pierces the ridge between the Pilarcitos and the San Mateo drainages. The water, after passing through this tunnel, is carried in a flume about 2 miles to the point where

San Mateo Creek is crossed from west to east. A second tunnel carries the water through the ridge between San Mateo and San Andres valleys. This tunnel is about 3 530 ft. long. At the westerly or San Mateo end of this tunnel the Locks Creek flume is joined by a flume from the north which adds San Mateo Creek water that has been diverted by a concrete dam from that creek. About 1.5 sq. miles of the watershed of San Mateo Creek lying next below the area for which Davis tunnel is an outlet are thus made partially tributary to San Andres reservoir.

The water consumption from the Peninsula reservoir system has been about 18 000 000 gal. per day. This is in round numbers at the rate of 530 000 gal. per day per sq. mile of tributary watershed. The amount of water wasted has been relatively very small, due to the large capacity of the reservoirs when compared with watershed areas. In years of ordinary rainfall Pilarcitos reservoir is the only one which is likely to be filled to overflowing, but as explained, nearly all of the surplus is conserved by the interceptingworks which carry it into San Andres reservoir. The overflow from the San Andres reservoir goes into the Crystal Springs reservoir, and the Crystal Springs reservoir has been full to overflowing only twice in its history, in 1889 and in 1895. The above-noted water production of 530 000 gal. per day per sq. mile may, therefore, be accepted as very nearly the normal for this region, in which 43 in. per year is the normal fall of rain.

When the amount of storage on the peninsula is compared with the amount of storage usually provided to equalize the flow of streams on the Atlantic coast, it seems large, but the need for the relatively large reservoir capacity results from the peculiarity of the climate. The rainfall records show that there may be two or even three years in succession in each of which rainfall is so light that there is very little run-off. To tide over such periods that are unproductive of water a large supply of water must be held over from the preceding seasons of more copious rainfall. Col. G. H. Mendell, who gave the subject much thought, reached the conclusion, as laid down in his report of 1877 on the San Francisco water supply, that so long as the city relied upon the coast range sources of supply the storage capacity of the reservoirs should be a 900 days' supply.

When a reservoir is located on a stream whose flow every year is adequate to fill it, this rule is, of course, without force. But even after some of the larger rivers of the state are made tributary to the established works, the storage of water in large quantity near the city is essential to make the service reliable.

The matter of securing other sites has been investigated and one at Belmont was selected for use as a feature of the Tuolumne River project. It goes without saying that the use of this site should only then be contemplated if the city fails to come to an understanding with the Spring Valley Water Company. The water company in extending its works from time to time naturally occupied the best and most available sites. The storage reservoirs now in use, particularly with the Crystal Springs dam raised to the full proposed height, will be adequate to meet every requirement.

The peninsula sources of water, which as described flow by gravity into San Francisco, are supplemented by Lake Merced. This lake lies close to the Pacific Ocean, just north of the southerly line of San Francisco. The elevation of its water surface at all stages is above sea level. The water in the lake, for the most part, is the outflow from the sand deposits that lie within the lake watershed. The surface run-off, which formerly reached the lake, is now intercepted and turned through a tunnel, past the lake into the ocean.

The lake has two arms that were originally connected by a narrow strip of water. They are now separated from each other by an earth dam. Structures have been built for the interconnection of the two lakes so that one pumping station may draw upon the water of both lakes. The surface area of Lake Merced is about 330 acres. When full its available contents are about 2 000 000 000 gal. The lake is not attractive as a source of water for domestic use, but for many years its water has been used mixed with the waters from Pilarcitos and San Andres reservoirs. It is protected against pollution by a system of works which intercept and deliver into the ocean the surface run-off from the inhabited portions of its watershed. These works include a brick conduit and tunnel from near the head of the south arm of the lake to the Pacific Ocean and a long flume from Ocean View; also a conduit for the Ocean View sewage. The large capacity and nearness of Lake Merced to the place of use will always make it a valuable addition to a municipal supply, even though no water be drawn from it except in case of emergency. When a Sierra Nevada water is added to the city water supply system the surplus should be allowed to flow into the Crystal Springs reservoir and into Lake Merced, thereby keeping these reservoirs as nearly full as practicable, and incidentally improving the quality of the stored water in each.

The value of Lake Merced as an emergency supply, if water

production may be considered, is not fully measured by its storage capacity, because the experience of the past indicates that it may be relied upon for a continuous supply of water amounting to about 3 000 000 gal. per day. The pumping station at Lake Merced has a capacity of about 7 000 000 gal. per day. It delivers water into the conduit that brings the water of Pilarcitos reservoir into the city.

So long as Lake Merced remains in use as a source of water, the human activities in the tributary watershed should be kept down as much as possible. Notwithstanding the works for the interception of surface drainage from the south and sewage from the east, there is a menace due to such activities that should be kept at a minimum. There is good reason, therefore, for preserving the lands near Merced Lake, if the city ever acquires them, as a park, whereby population can be excluded from the greater portion of the drainage basin and good police regulations can be enforced.

In 1887 it became apparent that the peninsula sources of water as then in use were inadequate to meet the demand for water. The immediate extension of the works to the easterly side of the bay of San Francisco was, therefore, determined upon. Rights to water in Alameda Creek had, as already stated, been secured, as early as 1875, by purchase of properties of the Alameda Water Company. This purchase included, besides these water rights, a part of a reservoir site on Calaveras Creek.

The Alameda Creek works, as commenced in 1887 and completed in 1890, were for the diversion of the natural flow of Alameda Creek at a dam about 2½ miles above Niles, and the delivery of this water by gravity flow through a long wrought-iron pipe conduit into a small receiving reservoir at Belmont, from which it is pumped through a pipe to Burlingame into the main from Crystal Springs reservoir.

The capacity of the works as thus constructed was about 7 000 000 gal. per day. They remained in service at this capacity for about 10 years, then the system was changed, by the addition of works higher up on Alameda Creek, and as a result of the change, which included a greater head to force water through the conduit to Belmont, the capacity of the Alameda Creek system was raised to about 10 000 000 gal. per day, at which it remained until further increased in 1903.

As now in use, the works include filtration in a large natural gravel deposit of the Suñol Valley. Water of Laguna (Alameda) Creek and of Calaveras Creek is brought within reach of this

gravel bed by a system of ditches. It sinks from these and from the natural channels into the gravel beds. It is intercepted in these gravel beds by a timber filter gallery placed in the bottom of a deep open cut, which is about one-half mile long and terminates in a concrete sub-surface aqueduct into which the water is also directly admitted through many small openings in its side walls. The concrete aqueduct is about 3 000 ft. long. It has a side feeder intended to more completely intercept the water coming down the creek channel. At its lower end it is connected with a gallery or conduit leading across Alameda Creek, from right bank to left bank, within the concrete diverting dam which has been placed across the Alameda Creek at the lower end of the Suñol Valley. This diverting dam is primarily intended to check any outflow from the gravel beds of Suñol Valley at less elevation than the crest height of the dam. The gravels are thus made to serve in some measure as a reservoir. The dam may also be used, if conditions require it, to divert the creek water directly into the conduit which takes it from this point down the Niles Cañon to the head of the pipe line.

The water from the Suñol Valley gravels, after crossing Alameda Creek as described, is carried by tunnel and flume along and in the mountain slopes on the south side of the cañon for a distance of 5 miles to a screen house, at elevation 180 ft., and there enters the pipe which conveys it to Belmont. About 3 miles of the 5 are in tunnel. The total length of the Alameda Creek pipe line from the screen house near Niles to the junction with the Crystal Springs main is about 29 miles. The pipe to Belmont is 36 in. in diameter, except where a slough and the Bay of San Francisco are crossed near and at Dumbarton Point. At each of these two places the water was carried in two 16-in. submerged pipes until 1902, when two submerged 22-in. steel pipes were added. The pressure main from the Belmont pumps to Burlingame is 36 in. in diameter. From Burlingame to Millbrae the 44-in. Crystal Springs main was paralleled in 1903 by a 54-in. main ni which the Alameda Creek water can be carried apart from the Crystal Springs water to the Millbrae pumping station and by the pumps there located can be forced into the San Andres main. The water supply from Alameda Creek is reinforced by the flow from 22 artesian wells in Livermore Valley near Pleasanton. A line of wells has been bored across the lower end of the Livermore Valley to the gravel beds, from which they bring to the surface about 7 000 000 gal. of water per day. This water is discharged into the creek and flows therein to the head

of a ditch which leads it into the Suñol Valley along or near the upper edge of the Suñol gravel deposits. The yield of the Alameda Creek system is now about 15 000 000 gal. per day.

There are a number of pumping stations connected with the water works. Some of these will be referred to in presenting salient features of the distributing system; others deserve special notice because of their peculiar function in transferring water from the lower to the higher levels.

The function of the Belmont pumps, as already explained, is to deliver Alameda Creek water either into the Crystal Springs main or to feed the Millbrae pumps for delivery into the San Andres main. The pumps at the Belmont station first went into service in 1888. New pumps were added in 1903. The present aggregate capacity of the pumps at this station is about 23 000 000 gal. per day.

The Millbrae pumps were installed with a capacity of about 16 000 000 gal. per day to force some of the water arriving in the Crystal Springs main into the higher San Andres main. Since the completion of the pressure main from Belmont to this station the Millbrae pumps serve also to send Alameda Creek water into the San Andres main.

The Pilarcitos pumps are located at the lower end of the outlet tunnel of the San Andres reservoir. The function of these pumps is to deliver San Andres water into the Pilarcitos main. Their capacity is about 4 000 000 gal. per day.

At Ocean View is an emergency pump of small capacity which serves the same purpose but has been but little used, if at all.

At the Crystal Springs dam is a pumping station which may be used to lift Crystal Springs water into a flume which carries it northerly into San Andres Lake. The capacity of the pumps here located is about 12 000 000 gal. per day.

The pumps at Lake Merced are connected with the San Andres and Pilarcitos mains in such a way that without loss of pressure the water from the San Andres main can be pumped into the Pilarcitos main. By suitable interconnection of pipes the two pumps at Lake Merced can be made to draw simultaneously either upon the lake or upon the San Andres main, or one pump can be fed from the main while the other draws its supply from the lake. The lake water, as already explained, is pumped into the Pilarcitos main and flows into Lake Honda receiving reservoir. The capacity of the Lake Merced pumps is about 7 000 000 gal. per day.

Before passing on to a description of the city distributing system it should be stated that all of the water, before delivery into the city receiving reservoirs, is screened. The screen house, near Niles on the Alameda conduit, is equipped only with wire mesh screens to remove occasional leaves and the like blown into the flume by the wind. The water which reaches University Mound reservoir all passes through a screen house there located. At this screen house, as at those on the San Andres line and at Lake Honda, the water is made to pass through ingeniously arranged screens of cheesecloth. After a set of screens has been in service about 1½ hours, the water is turned off and the screens are cleaned with a jet of water. Particles of vegetable matter, principally algæ, are removed from the water in this way. The screen house on the San Andres pipe line is located at the lower or easterly end of the outlet tunnel of San Andres reservoir. At Lake Honda is a screen house for the treatment of the water arriving in the Pilarcitos main.

Distribution.

San Francisco is a city of hills. The distribution of water under adequate pressure to all parts of the city is not, therefore, a simple matter. Some of the characteristic features of the distributing system as now in use are here briefly stated.

University Mound reservoir, capacity about 30 000 000 gal., located in the southeasterly portion of the city, at an elevation about 165 ft., receives the water from Crystal Springs reservoir with any added supply from Alameda Creek. The main conduit from this reservoir crosses Islais Creek on a trestle and supplies the low down-town section of San Francisco. The pumps at Black Point, which have a capacity of 5 500 000 gal. per day, draw upon this low-pressure system and serve the high-lying hilltops in the northern part of the city. Water is delivered by these pumps into the upper reservoir on Russian Hill and into the steel tanks on Clay Street hill and out on Presidio Heights. The Francisco Street reservoir, at elevation 140 ft., is at the end of a large main of the low-level system and serves admirably as a recipient of water during the night and a pressure equalizer during the day.

College Hill reservoir, in the south central part of San Francisco, receives the waters arriving in the San Andres main. The capacity of this reservoir is about 15 000 000 gal. Its elevation is 255 ft. It supplies a zone of very irregular outline next above the low-level area.

Lake Honda, located south of Golden Gate Park near the Almshouse tract, receives the waters of the Pilarcitos main. It has a capacity of 33 000 000 gal. Its elevation of 365 ft. gives it command of a region next above that served from the College Hill reservoir. The greater portion of the Western Addition is served from this receiving reservoir.

The highest district in the city now served with water is supplied through the Clarendon Heights pumps located at Seventeenth and Noe streets. The pumps have a capacity of 5 000 000 gal. per day. They can draw either upon the University Mound or the College Hill system. The pumped water is delivered into the Clarendon Heights tank, which is located on a spur of the Twin Peaks at an elevation of about 600 ft.

The gradual growth of San Francisco, and the need of keeping outlying districts, though sometimes sparsely populated, supplied with water, has led to the retention in use of much pipe of smaller diameter in many streets than would now be laid therein. The network of pipes now in use is not, therefore, fully up to the standard that would be prescribed for an entirely new system, particularly so long as water for extinguishing fires is supplied through the same mains which distribute water for other uses. Some idea of this fact results from a comparison of the pipes that would be required in a new distributing system (as planned in 1902) with the pipes now in use.

Pipes in Distributing System, 1902.

Diameter of Pipe, Inches.	Water Pipes of the Spring Valley System.		Water Pipes of the Proposed Tuolumne System (including Specials).	
	Wrought Iron, Feet.	Cast Iron, Feet.	Wrought Iron, Feet.	Cast Iron, Feet.
Specials		16 000		
3		130 809		
4		344 321		81 700
6		570 983		170 230
8		621 900		1 868 910
10		9 912		312 190
12		226 278		785 080
15	850			
16		121 154		752 780
20		21 840		90 960
22	25 481	23 488		52 740
24		20 820		395 540
30	12 669	4 494		227 830
33	2 510			
36			12 650	
37½	12 254			
44	7 213			
48			47 940	

Before the fire in 1906 there were in San Francisco about 50 000 connections with the Spring Valley Water Company's pipes. This number was reduced to about 30,000 after the fire. It is now in the neighborhood of 40,000.

Aeration and Measures to Prevent Pollution.

The water delivered to San Francisco comes in large part from storage reservoirs, in which its appearance and quality are without doubt improved. But as these reservoirs are fed by streams that are turbid during their freshet stages, and as they are located at low altitudes, exposed to the hot summer sun, it has not been possible to keep them entirely free from minute algæ and other vegetable growth. The screening process to which the water is subjected, as explained, removes much of this objectionable matter and the quality of the water is further improved by aëration, which is effected by discharging it upon an elevated platform from which it drips in successive stages to lower platforms. The water of the Pilarcitos pipe line and that pumped from Lake Merced are thus aërated on Daly's hill near the point where the Pilarcitos line crosses the south boundary of the city; the San Andres water is aërated just before being delivered into College Hill reservoir.

The main reliance for preserving the wholesomeness of the water supply is placed by the water company upon the protection of the watersheds against pollution. Over 2 700 acres, 4.4 sq. miles, or more than one half of the area tributary to Lake Merced, is thus owned. About 28 of the 36 square miles of watershed in whole or in part tributary to the Peninsula reservoirs are owned by the water company. On Laguna, Calaveras, San Antonio, Valle and Hondo Creek of the Alameda Creek system, the area owned is close upon 25 000 acres. On those portions of the watersheds where sources of pollution were most to be feared, the police control and the restriction of human activities have been made easy and effective by this policy of land ownership. The Coast Range sources of supply now utilized, or noted as within reach of the Spring Valley Water Company, are, nevertheless, not ideal sources of water for domestic use. The collecting ground is not of the high snowcapped mountain type, but is of the low soil-covered mountain and foothill character. Much of it is brush covered. Animal life and a certain amount of human activity in the watersheds, the natural turbidity of most of the water and the presence in it at times of more or less organic matter all point to filtration as a proper treatment

for the improvement of the water. Some of it, in fact, may be considered as already receiving this treatment. The water that issues from the Pleasanton wells has passed long distances through gravel deposits and that of Suñol Valley as collected in the filter galleries issues clear and inviting.

Undeveloped Sources within Control of Spring Valley Company.

Among the properties owned by the Spring Valley Water Company which have not been developed there may be noted:

Calaveras Valley on Calaveras Creek. — This is a reservoir site to which there are directly tributary about 100 sq. miles of the region round about and to the north of Mt. Hamilton. To this area about 40 sq. miles more can be added by diverting Hondo Creek waters into the Calaveras Valley. The rainfall on the watersheds that are or can be made tributary to the Calaveras Valley is only about two thirds of the rainfall near the Peninsula reservoirs. The water production will, therefore, be less. It will in a year of normal rainfall probably be about 225 000 gal. per sq. mile per day. The total water supply that can be hoped for from this source is not, however, to be deduced directly from this unit quantity and the drainage area. It will depend in a measure upon the extent to which the Hondo Creek waters can be intercepted, and in a large measure upon the amount of water that will reach the reservoir site in wet years in excess of storage capacity. The dam site for the Calaveras Valley reservoir has been thoroughly explored by the engineers of the Spring Valley Water Company and so far as has been disclosed by them the results of the examination are satisfactory. A dam with a crest 187 ft. above the natural surface of the ground would, according to estimates made by Mr. T. R. Scowden, who investigated this matter for San Francisco in 1874, create a storage capacity of about 30 000 000 000 gal. The run-off from the watersheds directly and indirectly tributary to the Calaveras reservoir will, in seasons with the maximum fall of rain, be more than twice this amount.

San Antonio Creek. — San Antonio Creek is a tributary of Calaveras Creek. On this creek a short distance above the point where it enters the Suñol Valley is a reservoir site to which about 40 sq. miles of the low mountain region northeasterly from Mt. Hamilton are tributary. On this watershed the rainfall is somewhat less than on that of the Calaveras reservoir. The amount of water which flows through the reservoir site

in a year in which the rainfall is normal is equivalent to an average flow of about 5 000 000 gal. per day.

It is to be noted that both the dam at the Calaveras site and the dam at the San Antonio site will hold back water that now flows to the Suñol gravels. There is, therefore, a certain interrelation between the amount of water produced by the intercepting works in the Suñol Valley and the water impounded in the reservoirs. This is also true of the proposed water development by storage on the Arroyo Valle. This last-named creek enters the Livermore Valley from the south and much of its flow sinks before reaching Pleasanton. It is a feeder and perhaps the principal feeder of the artesian strata from which the Pleasanton wells obtain their supply.

On the Arroyo Valle the Spring Valley Water Company has secured a foothold. It owns or controls a reservoir site of moderate capacity. The watershed tributary to this reservoir site is about 130 sq. miles, and the normal rain upon this drainage basin may preliminarily be taken at about 24 in. per year. The amount of water which flows through the reservoir site in a year with normal rain should be about 18 700 000 gal. of water per day.

On the Niles cone, too, the water company has acquired lands. The Niles cone is a flat gravel deposit which spreads out, fanshaped, from the mouth of Niles Cañon southwesterly across the valley region east of San Francisco Bay. It is permeated by the waters of Alameda Creek. These waters are within reach of pumps, and their development may in time be justified. As the total area of the watershed tributary to the Niles Cañon is about 600 sq. miles, and the three reservoirs above enumerated intercept (though only in part) the run-off waters from 310 sq. miles, there will always be some water, at least in wet years, from the other 290 sq. miles, together with the wastage from the reservoirs, to replenish the water of the gravel beds in Livermore Valley, in the Suñol Valley and in the Niles cone.

It will be readily understood that the lack of data, particularly in so far as they relate to the dimensions of structures by means of which water is to be stored, capacities of reservoirs to be created and capacities of conduits for the utilization of the water or its transfer to other reservoirs, as well as more or less uncertainty relating to rainfall and run-off, would render useless any attempt to now make a final estimate of the water production of the various sub-elements of the Alameda Creek

system. The daily watershed production above noted for the several reservoirs in years of normal climatic conditions on tributaries of Alameda Creek are only a first indication of possibilities. They cannot be fully realized. Even in the case of the Calaveras reservoir, which has a very large capacity, the inflow from the tributary watershed (including Hondo Creek) may in a single year of maximum rainfall be enough, as already stated, to fill the reservoir twice. Some water being assumed in storage at the beginning of such a season, there will then be large wastage, of which perhaps only a small portion may become available by infiltration into the Suñol gravels and the Niles cone. The proportional wastage in occasional years on the San Antonio and on the Arroyo Valle will be still greater, because the storage is there relatively smaller.

However, to give some idea of the total possible water production on Alameda Creek in its entirety, it may be stated that the mean run-off indicated by drainage area and rainfall is estimated at about 90 000 000 gal. per day. If this amount of water, or whatever the exact figure for the Niles Cañon flow may be, were intercepted by adequate devices above Niles Cañon, there would be no water for the Niles cone. This total, therefore, represents the extreme water production of the Alameda Creek watershed, including all local water consumption for whatever purpose and the waste, if any, by surface or subsurface routes to the bay.

San Francisquito Creek is frequently referred to as available for increasing the water production on the peninsula by about 7 000 000 gal. per day. This is probably an overestimate. It is understood that the Leland Stanford, Jr., University has a right to the first 3 000 000 gal. per day. As the run-off, estimated from the rainfall and the watershed of 15 sq. miles, will average only about 6 500 000 gal., this source should not be credited with a possible production of more than 3 000 000 to 3 500 000 gal. per day. On this creek there has already been constructed at Searsville a concrete dam 90 ft. high, which is to be raised to a greater height at some future time.

Of the various ocean slope creeks on the peninsula only one, as explained, Pilarcitos Creek, is at present made tributary to the established works. But it is generally admitted that if it were necessary to do so, though at relatively large expense, some additional ocean slope water could be intercepted and turned through a tunnel to the bay side of the mountains and ultimately into the Crystal Springs reservoir. To accomplish

this a long conduit of large capacity would be requisite. The ocean slope creeks afford but scant opportunity for storage at elevations that would permit water to flow from the collecting reservoirs into the Crystal Springs reservoir. The interception of storm waters would, therefore, be restricted to the short periods in winter when the creeks are high. During the rest of the year the natural flow of the streams is small, consequently only a small percentage of the annual output of the stream is then available for interception. A special study of the features of a project for the utilization of the ocean slope waters would have to be made before a close estimate of the probable ultimate yield of these sources could be made. But some idea of possibilities may be gained from the following: It is claimed that about 65 sq. miles of ocean slope drainages could be made tributary to an intercepting conduit with its head at Pescadero Creek. The run-off from this area, on which normal rainfall is about 40 in. per year, should average about 37 000 000 gal. per day, of which, depending upon the character and magnitude of the intercepting works, more or less would flow through the conduit. It is not at all improbable that about one half of this water can be made available, perhaps 20 000 000 gal. per day.

It now becomes possible to combine the foregoing figures relating to additional water development from sources that are near at hand and that are in whole or in part controlled by the Spring Valley Water Company. But to do this certain arbitrary assumptions must be made and these must be understood to be subject to modification as more data relating to storage possibilities, conduit capacities, rainfall and run-off become available. Thus it seems reasonable to expect that the Calaveras reservoir will make available about 25 000 000 gal. per day of the 35 000 000 that should flow through or past the reservoir in Calaveras and Hondo creeks. San Antonio reservoir may bring within reach 4 000 000 out of an average of about 6 000 000 gal. per pay, and on the Arroyo Valle about 10 000 000 gal. should represent the average amount intercepted.

The total run-off from the Alameda Creek watershed has already been noted at about 90 000 000 gal. per day. If the above amounts are realized on the tributaries named there will still be an average flow of about 51 000 000 gal. per day to feed the Pleasanton wells, the Suñol gravels and the Niles cone. As this water will come down the creeks mainly in wet winters when the creeks flash up quickly, a considerable portion thereof will

in all probability flow on to the bay and be lost. Some of it will be required for local use in Livermore Valley and elsewhere. It does not, therefore, seem safe to assume as a possibility that more than one half of the amount named, or about 25 500 000 gal. per day, can be intercepted by the Pleasanton wells, in the Suñol gravels and on the Niles cone, for delivery in San Francisco.

The water production of Spring Valley Water Company sources as developed and at ultimate capacity may, therefore, be tentatively stated as follows:

Sources.	Developed Supply. Gallons per Day.	Ultimate Supply. (Approx.). Gallons per Day.
Peninsula Reservoirs:		
Pilarcitos		
San Andres		
Crystal Springs	18 000 000	18 000 000
Lake Merced	3 000 000	3 000 000
San Francisquito Creek		3 500 000
Pescadero, and other ocean slope creeks		20 000 000
Alameda Creek:		
Calaveras Reservoir		25 000 000
San Antonio Reservoir		4 000 000
Arroyo Valle Reservoir		10 000 000
Pleasanton wells, Suñol gravels, Niles cone	15 000 000	25 500 000
Total	36 000 000	109 000 000

The foregoing statement in relation to the possible extension of the water works to other Coast Range sources of water is made to show that the possible expansion of the Spring Valley Water Company's system is not inconsiderable. It may also be noted that arrangements could be made to draw, in case of emergency, upon the great artesian water supply known to be within reach at the southerly end of San Francisco bay. A line of wells near Alviso would be a desirable addition to any water works system, but a draft upon such wells would, if long continued, have more or less effect upon the yield of the other wells in the Santa Clara Valley, and this source should not, therefore, be looked upon as available for large quantities of water except in cases of emergency and for short time periods only.

If the city were the owner of the water works under the circumstances, as above explained, attending their possible expansion, it would seem that the first step to take would be to supplement the developed supply by adding a large amount of

Sierra Nevada water. When this is accomplished the doubtful or least desirable sources now in use, such as Lake Merced, should, at least temporarily, go out of use. A time will then come when the works bringing to the city the mountain water will be taxed to their capacities. These works can then be added to and capacity increased until the limit of increase, indicated by the productiveness of the source, has been reached. This will be at a remote day, but when it comes recourse may still be had to the various additional nearby sources of water.

Supplemented by pure mountain water, the yield of the present sources of supply would be improved in quality. The peninsula reservoirs would be kept full of water or nearly so, and the Alameda gravels and Lake Merced would be called upon for water only when an emergency made this necessary.

The Tuolumne River Projected Development.

Although required, as city engineer, to plan water works with the Tuolumne River as the sole source of supply, the writer in his report on this project, and at other times, has pointed out that the needs of San Francisco would be best served by using the Tuolumne River sources in combination with the established water works system. No attempt has ever been made by him to belittle those advantages of the Spring Valley Water Works that are easily recognized in the nearness of its sources of supply to the place of use; in the reliability of the service rendered, due largely to the close proximity of some of its sources of supply to San Francisco and to works for safeguarding the service; in the large capacity of the storage reservoirs, which are close at hand, and in the fact that the service is an established one.

But the time is now at hand when a large addition to the water brought into San Francisco must be made, when it must be determined whether this addition shall be made by the Spring Valley Water Company or by the city; whether, in short, the water works that supply water to San Francisco are to be municipally owned or whether the established company should be allowed, as in the past, to expand its system by adding to it more water from Coast Range sources.

The writer's view that water consumption in San Francisco can be kept down to about 80. gal. per inhabitant is not shared by other engineers. Mr. Schussler, Mr. Stearns, Mr. Schuyler and others are of the opinion that the water consumption will increase much more rapidly than proportionally to population. They base their conclusions on the experience of

other large cities, notably of cities in the United States. Reasons for not accepting their conclusions have already been set forth. Be this as it may, the fact remains that San Francisco is a rapidly growing community, for which various forecasts relating to future population have been made, and that the growing city will demand more water from year to year.

The writer's figures relating to future population, as published in official reports, would probably have turned out to be underestimates if the city had not received the great setback resulting from the fire of 1906. They are given in the following table without correction for the loss of population in 1906, together with the estimates made by Mr. Schussler. It now seems probable that in ten to fifty years the actual population, unless increased suddenly by the addition of new territory, will lie somewhere between the figures noted in the table.

Population and Water Consumption Forecasts.

	Population.		Water Required, Gallons per Day.	
	Grunsky.	Schussler.	Grunsky.	Schussler.
1910.....	415 000	500 000	33 100 000	40 000 000
1920.....	490 000	650 000	39 200 000	55 000 000
1930.....	570 000	800 000	45 600 000	72 000 000
1940.....	650 000	950 000	52 000 000	90 000 000
1950.....	735 000	1 100 000	58 800 000	110 000 000

(Tuolumne) Quantity.

The quality of the water at the selected reservoir sites on Tuolumne River was investigated with satisfactory result. The question next to be answered related to the quantity that could be made available. On this point the writer, in his official reports, has been conservative. This question was treated throughout from the point of view that the Tuolumne River would be made the sole source of supply. The water production in a year of minimum rainfall was, therefore, used as a basis for the discussion of quantity that could be delivered, while the increase that would result from holding water over from one year to another in special storage reservoirs was not taken into account. Neither was any full discussion attempted of the amount of water development that would be possible by increasing storage at the selected sites by building higher dams. It was enough for the purpose of the reports on this subject to show that a development of water in large quantity was possible and that after the

needs of prior users on the stream were supplied there would be enough left to warrant the construction of the water works.

In the writer's official report on the Tuolumne River project it was shown that Lake Eleanor reservoir, if given a useful capacity of 12 000 000 000 gal., would be nearly twice filled in years of normal rainfall, and in years of minimum rainfall about three fourths by the run-off from the area directly tributary to the lake, and that the addition of other waters by interception, notably Cherry Creek, would bring to the reservoir in any year more water than required to fill the empty reservoir. Likewise it was shown that no year is to be expected in which the water flowing through Hetch Hetchy Valley will not be 20 to 25 per cent. greater than the proposed storage capacity of the reservoir.

The areas of the watersheds which are tributary to Hetch Hetchy Valley and to Lake Eleanor have been estimated at 452 and at 84 square miles respectively. The drainage basin of the Tuolumne River at La Grange, where the diverting dam of Turlock and Modesto irrigation districts is located, is 1 501 sq. miles. It follows, therefore, that there will be left in the river much of its natural flow entirely undisturbed by the works proposed for San Francisco.

To make a satisfactory estimate of the quantity of water that can be developed on the Tuolumne River for use in San Francisco more data are required than are now available. It is necessary in this case to know not only how much water per annum reaches the reservoir sites and the capacities of the reservoirs and conduits, but also to know the demands that will be made upon the river by other users of its waters. It is known that the river in the winter and spring months has a large flow, occasionally sending into San Joaquin Valley in 4 or 5 days as much water as would fill the proposed storage reservoirs. The retention of such storm waters in mountain reservoirs would admittedly be beneficial to all persons located on the river or using any of its waters. During the high stages of the river natural flow would supply all demands and there would be excess for storage. It is probable that the reservoirs would be drawn upon not more than 8 months in any year. Their proposed capacity, therefore, enables a first approximation to be made of the amount of water to be expected from this source. Estimated on this basis at least 170 000 000 gal. per day should be obtainable.

That this is a conservative estimate and will be materially

increased when more precise information is available appears from the following considerations:

The assumed minimum annual rainfall on the tributary watersheds will fill the reservoirs. This minimum is 18 in. per annum. It is in all probability too low, and if too low much more water will be available for storage than has been assumed, and larger reservoirs would be justified to equalize the river's flow.

No supplemental storage to equalize the flow, as between years of copious rain and years of light rainfall, has been assumed. Such additional storage is possible in the Hetch Hetchy Valley by constructing a higher dam and is possible in other sites of the Tuolumne basin. It is also obtainable near San Francisco, particularly if the Tuolumne project is made supplemental to the Spring Valley system.

The determination of the run-off in a year of light rainfall is, in other words, only a first safe approximation of the amount of water to be expected, and it is in this sense that the above estimate should be accepted.

(Tuolumne) Storage-Basins and Conduits.

The works by means of which it was proposed by the writer to make Tuolumne River water available in San Francisco may be briefly described as follows:

The granite gorge at the lower end of the Hetch Hetchy Valley is to be closed by a masonry dam rising to a height of 150 ft. above the valley floor. The gorge at the surface of the river has a width of 136 ft. The crest length of the dam, 150 ft. high, would be 400 ft. The dam would be arched upstream and surplus water would flow over its crest. Above the dam would be a bridge. The surface area of the reservoir would be about 1 180 acres. Its storage capacity would be 33 000 000-000 gal.

The additional storage at Lake Eleanor is to be secured whenever conditions make it desirable to regulate the flow of Tuolumne River still further than would be possible by a dam at Hetch Hetchy Valley alone. The Lake Eleanor dam would be located about $1\frac{1}{4}$ miles below the lake on a solid rock ledge. It would be about 75 ft. high, slightly arched upstream, and would have a length of 1 300 ft. The total amount of water impounded by it would be about 13 000 000 000 gal., of which about 12 000 000 000 gal. could be made available.

When still further storage is needed the first step to secure

it will be to raise the Hetch Hetchy dam. An added height of 50 ft. would about double the storage in Hetch Hetchy Valley. The higher dam would be quite feasible.

Except at times when the reservoirs are full and water is wasted over the tops of the dams, the outflow from the reservoirs would be under control. The outflow from the Hetch Hetchy reservoir would flow in the deep gorge of Tuolumne River about 16 miles from the point where it is discharged through the reservoir outlet works to a diversion point at or a short distance below the mouth of Jawbone Creek. A point about one mile below Jawbone Creek has been tentatively selected as the diversion point. Water from Lake Eleanor reservoir would also reach this point by flowing down Eleanor Creek to Cherry Creek and down Cherry Creek to the Tuolumne River.

It is to be assumed that at this point the river water will rarely, if ever, be turbid. The diversion will, therefore, probably, be practically continuous. Suitable provision for keeping drift out of the conduit and for sluicing out sand deposits will, however, be made. The water taken out of the river will be carried in canal and tunnel, with occasional inverted siphons (as across the cañon of the South Fork), about 28 miles to a mountain spur from which, in a distance less than 2 000 ft., a drop of 766 ft. is available for the generation of power. This is at Bear Gulch.

Below Bear Gulch the canal will be cut into the mountain slope on the south side of Tuolumne River at an elevation about 350 ft. above the water surface of the river. The conduit at Moccasin Creek will be an inverted siphon of iron pipes about a mile long. When Red Mountain Bar is reached Tuolumne River will be crossed, also in iron pipes forming an inverted siphon. The water discharged by this siphon on the right or northwesterly bank of Tuolumne River will flow a short distance, about 640 ft., in an open canal. It will then enter a tunnel 2 660 ft. long, will be piped across a depression 4 450 ft., will enter another tunnel 1 130 ft. long, will be piped across another depression, and will then enter a tunnel 11 430 ft. long that will discharge it into the watershed of Dry Creek. A short canal will carry it to a point from which it can be dropped 330 ft. to the elevation selected for the head of the pipes across the San Joaquin Valley.

Both the drop at Bear Gulch of 766 ft. and that at Dry Creek of 330 ft. are to be utilized to generate power which can

be transmitted electrically across San Joaquin Valley and there utilized to pump the water over the Livermore pass at Altamont. Suitable power installations are to be made for this purpose. It will not, however, be necessary to erect a power station at Dry Creek so long as only a part of the water arriving at Bear Gulch will be required for use in San Francisco. Power generation may thus, for many years, be confined to the single station.

The surplus water there used for power will be a part of that which would under any circumstances have been allowed to flow in the river to La Grange for the irrigation canals.

After passing the Dry Creek power station the water will be delivered into the San Joaquin Valley pipes from a small reservoir. Local run-off is to be excluded from this reservoir, and it will be equipped with adequate outlet structures to screen and control the water flowing into the pipes and to drain the reservoir when necessary. The water surface in this reservoir is to be at 567 ft. above city base.

Across the San Joaquin Valley, in a direction almost due west, the water will be carried 60.5 miles in riveted pipes 48 in. in diameter. Stanislaus River will be crossed on a bridge, a long stretch of land subject to occasional overflow will be crossed on a trestle and the San Joaquin River, which at certain seasons of the year is navigable, will be crossed in submerged pipes. The project as outlined made provision for two 48-in. pipes across the San Joaquin Valley. In case that the Tuolumne project is to supplement the Spring Valley system, only one pipe would at the outset be required, and this would perhaps be of some other diameter probably somewhat larger.

The San Joaquin Valley pipes will discharge into a receiving reservoir at the Altamont pumping station, and from this reservoir the water is to be pumped over Livermore Pass. The receiving reservoir will be at elevation 155 ft. and the Altamont reservoir at elevation 740 ft. above city base. Allowing for the friction in the force mains, the pressure at the pumps will be equivalent to a head of about 625 ft. The pumping plant is to be of high duty, arranged for operation with electrically transmitted power. Some steam power is to be held in reserve for use in emergency.

On the summit at Livermore Pass the water will be discharged into the Altamont reservoir, which is to have a capacity of about 200 000 000 gal. This reservoir is at the head of the long line of pipes in which the water will be carried into

STANISLAUS
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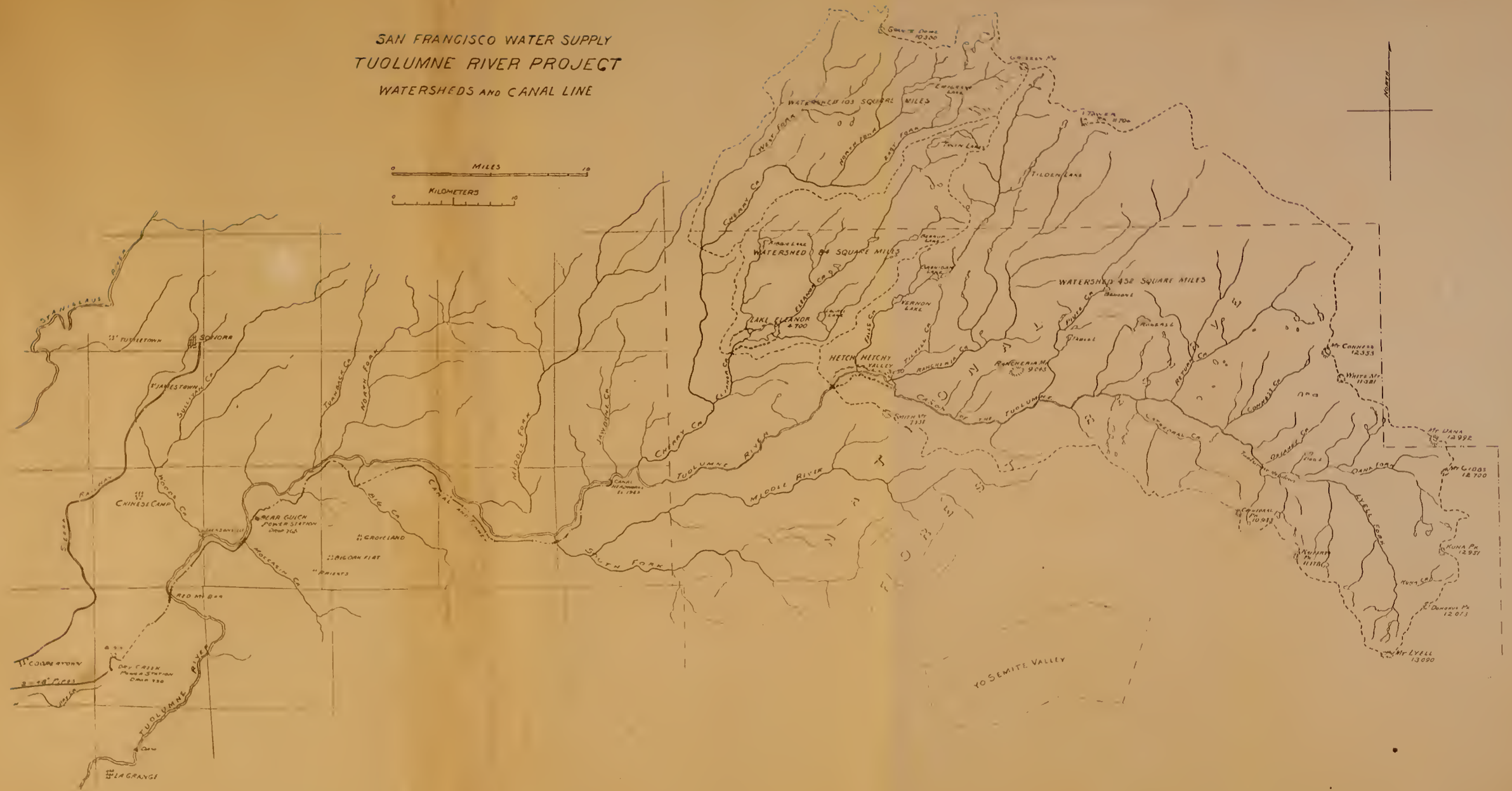
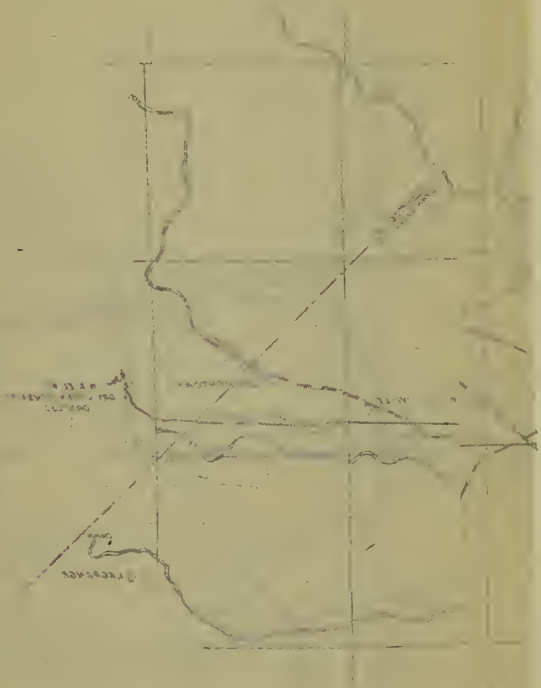
DITCH


SAN FRANCISCO WATER SUPPLY
TUOLUMNE RIVER PROJECT
WATERSHEDS AND CANAL LINE
MILES
KILOMETERS
NORTH
WATERSHED 103 SQUARE MILES
WATERSHED 84 SQUARE MILES
WATERSHED 432 SQUARE MILES
LAKE ELEANOR 4700
HETCH HETCHY VALLEY
CANYON OF THE TUOLUMNE
TUOLUMNE RIVER
MIDDLE RIVER
SOUTH FORK
MIDDLE FORK
NORTH FORK
WEST FORK
EAST FORK
CANAL TUNNEL
CANAL
YOSEMITE VALLEY
SONORA
JAMESTOWN
TUSCUMNE
CHINESE CAMP
BEAR GULCH POWER STATION
GROVELAND
BIG OAK FLAT
PRIENTS
RED MT. BAR
DRY CREEK POWER STATION
LA GRANGE
DAM
MT. CONNESS 12,953
MT. DANA 13,992
MT. LYELL 13,090
KUNA PK. 12,951
MT. GIBBS 12,700
MT. CHAMBERLIN 11,170
MT. DONOHUE 12,073
RANCHERIA MT. 9065
SMITH MT. 7331
WHITE MT. 11,981
TILDEN LAKE
VERNON LAKE
TWIN LAKES
EMERALD LAKE
RANCHERIA
PUTNAM
CRANE
DESOLATE
DANA FORK
LYELL FORK
KUNA CR.
CLEAVER
CLAVEY
CLAVEY CR.
LAKE CR.
TURNER CR.
RANCHERIA CR.
PUTNAM CR.
CRANE CR.
DESOLATE CR.
LAMBERT CR.
MOCCASIN CR.
ALIG CR.
SULLIVAN CR.
TUOLUMNE CR.
MOORE CR.
SIERRA RAILWAY
STANISLAUS RIVER



SAN FRANCISCO WATER SUPPLY

TUOLUMNE RIVER PROJECT

PIPE LINE ACROSS SAN JOAQUIN VALLEY

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SAN FRANCISCO WATER SUPPLY
TUOLUMNE RIVER PROJECT
PIPE LINE
ALTAMONT TO SAN FRANCISCO
SAN FRANCISCO
OAKLAND
SAN FRANCISCO BAY
PACIFIC OCEAN
COLMA
SAN BRUNO
HILLSBORO
REDWOOD CITY
MENLO PARK
RAVENSWOOD
NILES
ALVARADO
CENTERVILLE
NEWARK
IRVINGTON
MISSION SAN JOSE
LIVERMORE
ALTAMONT PASS
ALVISO
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and across Santa Clara Valley. The route of the conduit will be westerly through the Livermore Valley across a ridge of hills between Valle and Calaveras creeks, where there will be a tunnel 1 mile long, thence crossing the Calaveras Creek and over the ridge west of this creek into the Santa Clara Valley. At the point where Santa Clara Valley is reached a drop of 80 ft. is practicable. It may, upon further study, be found desirable to utilize all of this extra head in the conduit, thereby reducing the size of pipes somewhat. Under the project as outlined in the official report, here (as across the San Joaquin and Livermore valleys) two lines of 48-in. riveted iron pipe each with a capacity of 30 000 000 gal. will be requisite. The route of these pipes will be around the southerly end of San Francisco Bay and thence northwesterly and northerly to an entrance into San Francisco by way of Colma. The location of the main supply pipes within San Francisco will be on the westerly slope of the main peninsula ridge, at an elevation between 200 and 220 ft., to the Ocean House road; along this road a short distance, thence by tunnel to the easterly side of the ridge at about elevation 214 ft.

For a system of water works, with Tuolumne River as the sole source of supply, it would be necessary to provide storage facilities somewhere near San Francisco for at least a 30-day supply. Much more would be desirable, because the water works of a large city should be amply safeguarded. No large reservoir site in or near San Francisco has been discovered at sufficient altitude to permit delivery of water from it to San Francisco by gravity flow. The best site that has been discovered is located near Belmont. By means of a dam rising to a height of about 105 ft. above the present surface of the ground, water can there be impounded to the extent of 3 000 000 000 gal. — a 50-day supply when the water consumption of the city has reached 60 000 000 gal. per day. The water surface in this reservoir would be at elevation 177 ft. above city base, not high enough to flow over the divide near Colma.

The Belmont reservoir would be filled from the Tuolumne mains and the water there stored would in the case of an emergency be pumped into San Francisco through the northerly section of the main pipes. Under the project as outlined a pump capacity of 30 000 000 gal. per day was proposed for this point.

(Tuolumne) Distribution System.

There would be two receiving reservoirs in San Francisco,

one with a capacity of 100 000 000 gal. on the House of Refuge lot, at the intersection of San José and Ocean avenues, and another east of Mission Road, just south of Amazon Avenue. The arrangement of the discharge into the receiving reservoirs is to be such that the full volume of water reaching the city can be sent into either of them. The elevation of these reservoirs would be 196 ft.

The distributing system that would be necessary for the water arriving in the city as described was carefully studied. To maintain adequate pressure, and yet avoid excessive pressure in the pipes, it was found desirable to arrange the water distribution in 5 levels, of which the low level alone was to be served by gravity flow direct from the receiving reservoirs. All other levels were to be served from two pumping stations, one located in the block bounded by Seventeenth, Eighteenth, Diamond and Eureka streets, and the other located near the House of Refuge receiving reservoir.

On the low-level system there were to be three reservoirs and two tanks with a combined storage capacity of 26 912 000 gal.

On the second level there would be two reservoirs and two tanks with an aggregate storage capacity of 29 830 000 gal.

On the third level there would be one reservoir and seven tanks with an aggregate storage capacity of 3 233 000 gal.

On the fourth level the storage to be provided in three tanks would be 1 448 000 gal.

On the fifth level in two tanks storage to the amount of 1 300 000 gal. would be provided.

The combined storage capacity of all the reservoirs on the city distributing system, including the two receiving reservoirs, would be 218 343 000 gal.

It is not necessary to describe the distributing system in detail. This paper would become too long if this were attempted. The diagrams and general location maps further illustrate the salient features of the project. It should, however, be stated that the distributing system of reservoirs, pumping plants and interconnecting pipes of the Tuolumne River project were planned to meet fully the requirements of the city. On this subject the report of 1902 may be quoted: "At the special request of the Fire Department, the smallest pipes on main streets have been planned 8 in. in diameter. This is in some cases, perhaps, in excess of immediate requirements, but as the pipes laid would serve from 50 to 100 or more years, and the additional cost involved is small, it was thought advisable to

comply with this request. The smallest mains in streets of secondary rank, and where only one or two fire hydrants are to be served, are to have a diameter of 6 in."

The distributing system thus planned would have been superior to the pipe system and reservoirs now in service. However, in the report on the Tuolumne River project, in discussing the same as a project to supplement the established works, the writer says:

"The city distributing system [of the Spring Valley Water Company] would come into use without modification, except the placing of larger mains in some sections of the city to insure the best possible fire protection, and the construction of a number of new reservoirs and tanks and an improvement of the pumping facilities. It is thought that an expenditure of $1 000-000 in betterments of this kind would be at once justified if the Spring Valley Water Works were augmented by a supply from the Sierra Nevada, and that about $500 000 would cover the cost of the receiving reservoir at the House of Refuge lot, and its service mains."

(Tuolumne) Purity.

In the progress report already referred to, after quoting Col. G. H. Mendell's favorable opinion of the high mountains of the Sierra Nevada (3 000 or 4 000 ft. upward to the summit ridge) as a source of water for municipal use, the writer says:

"Further observations have confirmed this view, and from personal examinations of the drainage basins of the rivers descending these western slopes, from the Yuba southward to the Merced, it is to be added that in other respects some of these drainage basins are ideal drainage grounds for a city water supply. The snow which accumulates during the winter and is not all melted until midsummer performs the same function as storage reservoirs, equalizing the flow of the rivers. The severity of the climate and the ruggedness of the regions of high altitude in the Sierra Nevada render them uninhabitable, and, it might almost be said, inaccessible for the greater portion of the year. Great areas, particularly southward from the drainage basin of the Stanislaus River, have in the past been accessible for pasturage only to a very limited extent, and they are now still protected against occupancy by man by being made national parks and forest reserves. The high Sierra is a region of granites, slates and lava, much of it bare, not yet covered with soil. Over vast areas the recent action of glaciers is traceable.

"The polished striated surfaces of the granite still glisten in the sunshine. Hundreds of small lakes have been carved out of the original surface of the country by the glacial action, notably in the region which includes the headwaters of the

Stanislaus, Tuolumne and Merced rivers, and the other streams of the Sierra Nevada further to the south. Other lakes are formed, in part at least, by the terminal moraines of glaciers, which have been left as barriers across the original outlets of valleys . . . " Throughout the high mountain region, and particularly in those portions thereof which show marked glacial action, lakes, as already stated, are numerous. Some of these are of considerable size, among the best known being Blue Lakes, Lake Eleanor and Lake Tenaya. The water of these lakes is, almost without exception, of remarkable purity. A large number have been personally visited and no reason seems apparent why the water of those of the glaciated, uninhabited high mountain regions southward from Lake Tahoe should not be considered equal in quality or even preferable to the water of Lake Tahoe, around which there will always be more or less marginal land available for human occupancy and desirable as a summer resort."

The quality of the water obtainable from Tuolumne River may be judged from the analyses made by the city chemist, Mr. Frank T. Green, in 1903.

Two samples of water were taken in sterilized large bottles by a chemist, Mr. J. H. Gray, acting under the writer's direction, the one from Lake Eleanor on September 30, 1903, the other on the same day from Tuolumne River in Hetch Hetchy Valley. The river was at that time at a low stage. The sample from the lake, it was thought, might be regarded as typical of the water that would be held in the enlarged Eleanor reservoir and in the proposed Hetch Hetchy reservoir. The results of the analysis were favorable, as will be seen from the following, submitted by Mr. Green under date of November 7, 1903.

	Lake Eleanor. Parts in 100 000.	Tuolumne River. Parts in 100 000.
Total solids	1.4	3.0
Loss on ignition	0.4	0.4
Fixed residue	1.0	2.6
Chlorine as chlorides	0.198	0.357
Oxygen consumed	0.132	0.07
Nitrogen as albuminoid ammonia	0.006	0.005
In first 50 cu. cm.	55%	53%
In second 50 cu. cm.	37%	26%
In third 50 cu. cm.	8%	13%
In fourth 50 cu. cm.		8%
Nitrogen as free ammonia	0.004	0.0024
In first 50 cu. cm.	50%	77%
In second 50 cu. cm.	34%	18%
In third 50 cu. cm.	16%	8%
Nitrogen as nitrites	0.00003	0.00004
Nitrogen as nitrates	0.0024	0.0012

QUANTITATIVE (ACIDS AND BASES).

PARTS IN 100 000.*

	Lake Eleanor.	Tuolumne River.
Total solids	1.40	3.00
Fixed residue	1.00	2.60
Silica, SiO_2	0.307	0.567
Magnesia, MgO	0.028	0.060
Iron and alumina, Fe_2O_3, Al_2O_3	0.017	0.057
Lime, CaO	0.127	0.377
Sulphur trioxide, SO_3	0.101	0.131
Sodium chloride, NaCl	0.327	0.590
Carbon dioxide and undetermined	0.093	0.818

CALCULATED INTO SALTS.

PARTS IN 100 000.

Calcium sulphate, $CaSO_4$	0.1717	0.222
Calcium carbonate, $CaCO_3$	0.1014	0.509
Magnesium carbonate, $MgCO_3$	0.0588	0.126
Sodium chloride, NaCl	0.3270	0.590
Silica, SiO_2	0.3070	0.567
Iron and alumina, Fe_2O_3,Al_2O_3	0.0170	0.057
Undetermined	0.0171	0.529

It is reasonably certain that Tuolumne River at its high stages would show still less of total solids in solution.

The following analysis of a sample of Lake Tahoe water, taken on October 16, 1900, was made by Mr. J. H. Gray, acting under the writer's direction. It is noted for comparison and to show the general excellency of the waters originating in the high mountains of the Sierra Nevada.

LAKE TAHOE WATER.

PARTS IN 100 000.

Total solids	6.5
Loss on ignition	1.5
Fixed residue	5.0
Chlorine	0.142
Nitrogen as nitrites	None
Nitrogen as nitrates	Trace
Nitrogen as free ammonia	0.0006
Nitrogen as albuminoid ammonia	0.0034
In first 50 cu. cm.	71%
In second 50 cu. cm.	23%
In third 50 cu. cm.	6%
Oxygen consumed	0 010
Bacteria at 100 yds. off shore per cubic centimeter	1
Bacteria at 200 yds. off shore per cubic centimeter	0
Bacteria at 300 yds. off shore per cubic centimeter	0
Bacteria at 500 yds. off shore per cubic centimeter	0

* One Liter, the quantity used for each estimation, except in case of sulphates, then 500 cu. cm.

The water for the bacteriological examination was taken at a later date. It was plated immediately upon being taken and the results noted are considered reliable.

A sample of water for bacteriological examination from near the lake outlet taken at the same time that the samples for chemical analysis were taken showed a few bacteria (60 per cubic centimeter are recorded, page 344, Appendix Municipal Reports of San Francisco, 1900–1901), but it is noted (on page 379) that the determination of the number of bacteria should be ignored because immediately after the samples were taken a light flaky substance was noticed in the water, and because a delay in transportation occurred, making the time two days before the samples reached the laboratory.

Analyses of the waters that were being furnished to San Francisco in 1900 and 1901 by the Spring Valley Water Works were also made. The results are published in the Municipal Reports of 1900–1901, Appendix page 353 *et seq.* Later analyses in large numbers have been made by the city chemist under direction of the board of health.

(Tuolumne) Cost.

In 1902 a cost estimate was made of water works with Tuolumne River as the sole source of supply. The capacity of the works, which were made the basis of the cost estimate, was 60 000 000 gal. per day. The money, to be raised by a bond issue, was estimated at $39 531 000. This includes $8 807 000 for a distributing system. Interest during construction was not included because no part of the interest on the bonds would be paid out of the construction fund resulting from the sale of bonds.

Six years have elapsed since the cost estimate was made. Since that time the country has been swept by a wave of prosperity attended by a material increase of prices of materials and of wages and this wave has been followed by a period of more or less business depression attended by falling prices of materials and by a lower wage scale. The cost estimate, therefore, needs some revision. This revision and a suitable adjustment of the works to altered requirements would be all the more necessary if the project is to be so modified that it will supplement the Spring Valley system.

The cost estimate of the Tuolumne River water supply project, made by the writer as city engineer, was based on surveys and examinations covering all parts of the project. The

reservoir contents were determined from contour lines surveyed by the United States Geological Survey. The dams at Lake Eleanor and across the Tuolumne River at the lower end of the Hetch Hetchy Valley were planned after the sites had been surveyed and examined in person. The route for the canal and tunnels and pipe lines was surveyed throughout. The distributing system in the city, including receiving and distributing reservoirs and pumping stations, was worked out in sufficient detail to show location and plans of proposed structures and the complete network of pipes required. The maps and diagrams that were prepared to illustrate the project and to accompany the report were 36 in number. They are enumerated in the letter transmitting the Tuolumne River report. This enumeration does not, however, include the plane table survey sheets, of which there were a large number showing the conduit route.

In the water rate cases still pending, the engineer experts of the Spring Valley Water Company call attention to the underestimate of the cost of the proposed Tuolumne River project. These experts all testify to the need of carrying the water from the proposed point of diversion from Tuolumne River, — in fact, from the mouth of Cherry Creek some miles further upstream, — to San Francisco in covered conduits. Reservoirs, notably the Hetch Hetchy itself, which is located in the mountains at an altitude of 3 600 ft., are referred to as exposed to the hot sun, and this is noted as detrimental to the water quality. These criticisms are made, first, to discredit the superior quality of the mountain water as delivered, and, second, to establish a high cost of works for purposes of comparison with the Spring Valley system.

Among the engineers who have thus declared it to be necessary to cover the proposed open canal are Mr. F. P. Stearns and Mr. Jas. D. Schuyler. Their testimony is best refuted by quotations from a report in which they both joined a few months later.

Mr. Stearns, testifying in 1905 relating to the open canal section of the Tuolumne project, says:

" In an unlined open canal on a steep hillside, as in this case, water would deteriorate in quality both by its exposure to the sun in the shallow canal and by opportunity afforded for the pollution of the water; some would be lost by filtration, and such a canal would be more liable to accidents and interruption than a tunnel. It would seem to me advisable, in view of the very great length and cost of the work, that this portion should be built wholly in tunnel, fully lined, so that the works would

be less liable to interruption and to the liability of pollution and deterioration of the water which I have spoken of."

Mr. Schuyler in the same connection says:

"I do not believe that the water would maintain its purity after it left the headworks unless the scheme as outlined by him were to be materially changed and the water carried throughout in closed conduits. The proposition of carrying the water for 27 or 28 miles in open ditches along the mountain sides is one which must necessarily lead to constant pollution of the supply, not only from matter picked up from the bed and banks of the canal as it passes along, but it would be exposed to the action of the sun throughout that distance and subjected to the pollution from the drainage of the pastures through which it passed and subject to pollution from the wash of the mountain sides in storms and also from landslides from the mountains; the blowing of dust and leaves and other matter borne by the winds and deposited in the canal would further add to the pollution of the water."

Most of this open canal is to be along steep hillside. The following extracts are from the city engineer's report of 1902:

"The bottom width of the canal will be 9 ft.; the proposed depth of water 5 ft." "Rain water accumulating on the hillsides above the canal is to be intercepted by a proper system of small ditches which will lead the water into ravines for which a crossing over or under the canal will be provided in each case as may be best adapted to local conditions."

After flowing down the Tuolumne River some 16 miles, and then in conduits, of which about 28 miles are of the uncovered type, the water will pass through two small reservoirs at the head of the Dry Creek power station, through a small reservoir at the head of the San Joaquin Valley siphon, through a small reservoir at the Altamont pumping station, through a reservoir having a capacity of 206 000 000 gal. at Altamont summit, besides 152 miles of tunnel and pipe, and if it should be thought desirable, can be made to flow through the proposed Belmont reservoir whose capacity is estimated at 3 000 000 000 gal., though this would involve some additional pumping.

With these facts in mind Messrs. Stearns and Schuyler may be again quoted. They joined with Mr. John R. Freeman, in a report dated December 22, 1906, on the project now accepted of supplying Owens River water to Los Angeles through a conduit 231 miles long. They say in this report:

"Our examination of the streams in the Owens Valley showed that the creeks coming from the Sierras furnished water which is clear, colorless and attractive; the water in the river,

being made up of the combined flow of these creeks, is of similar character, but has a slight turbidity and stain, owing apparently to drainage from the marshes in Long Valley and to other return water from the canals and irrigated lands. This feature would make the water somewhat objectionable if it were to flow directly from the river into the city pipes, and [but] it has little or no significance in the present instance where the water, after being taken from the river, is to be held for a long time in a large storage reservoir where the mineral particles which produce the turbidity will have time to settle. The long period of storage in the reservoir will also be an important safeguard against the transmission of disease germs should any enter the water of the river, because it has been found, both by experiment and experience, that disease germs are all, or nearly all, destroyed where the water is held sufficiently long in reservoirs."

The Los Angeles conduit, as recommended by the engineers above named, will be an open canal for 20 miles in Owens Valley; thence, still in this valley, for 40 miles it will be an open canal lined on bottom and sides with masonry laid in Portland cement. The next 15 miles of the conduit are also to be of the open type lined with masonry. In the following 24.5 miles there will be a reservoir of tunnels, siphon pipes and sections of bench conduit along mountain sides, the latter covered at the outset with reinforced concrete. Then come 20 miles of open, lined canal of easy excavation, with less than 4 000 ft. of steel flumes and pipes crossing dry wastes. All of the next 21.5 miles of the conduit will be under cover. The canal then emerges upon the smooth plains of Antelope Valley and will be lined, but without cover, for 64.5 miles. This stretch of the conduit is followed by a tunnel nearly 5 miles long to San Francisquito Cañon. The water is to flow down this cañon 11 miles until its use for power development becomes sufficiently important to justify the substitution of an artificial conduit. From San Francisquito Cañon to the head of the San Fernando Valley the water will be carried 15.18 miles in tunnels, siphons and covered canal.

Of the 164.5 miles of the lined section of the Los Angeles aqueduct, 19.8 miles are to be put under cover. The rest of the lined sections, 144.7 miles, are to be left open for the first five years of operation. The 22.2 miles of unlined canal are to remain open permanently, and the 11 miles of natural water course for an indefinite period, to say nothing of the flow of the water for many miles in Owens River above the proposed point of diversion.

The consulting engineers say of this project: "We find the project admirable in conception and outline, and full of promise for the continued prosperity of the city of Los Angeles."

Compared with Owens River the Tuolumne River is a far more desirable source of supply. Are not, therefore, the same words of praise applicable to the Tuolumne River project, in so far as the source of supply and the compared features of the project are concerned?

It is not necessary to notice other criticisms of the Tuolumne River water supply project by the engineer experts who testified for the Spring Valley Water Company. These, particularly such as those relating to the city engineer's failure to include in his cost estimate interest during the construction of the works, must be assumed to have originated in a desire to show a probable high cost for any system of water works independent of the Spring Valley system, in order that any weight given to a comparison with the cost of bringing in other water may be in favor of a high valuation of the Spring Valley Water Company's works. The matter of interest during construction is referred to in the city engineer's report, but was not included in the cost estimate to be used as a basis for a bond issue, because, as already stated, it was not proposed to make it a part of the bond issue. It is admittedly an expense connected with water works construction, but in the case of a municipality the fund out of which to pay it originates in the tax levy and is not a part of the fund resulting from sale of bonds as is usually the case when private corporations proceed with construction of works under a bond issue. Its omission from a cost estimate which was to serve as a basis for a municipal bond issue was not, therefore, an oversight.

Succinct Statement of Conclusions.

In weighing the merits of sources of water for the supply of San Francisco particular attention must be given to the following points:

The quality of the water.

The quantity of water that can be made available.

The reliability of the service.

The cost.

The main consideration is quality. The water supplied to a municipality must be pure and wholesome. It should be above suspicion. The best water within reach of San Francisco, in the light of all the information now available, is the water of the high Sierras. In the Sierra Nevada Mountains there are great areas of uninhabitable territory. Regions are there to be found to which human activities are not likely to be attracted,

and of these, many, by inclusion in national forest reservations and parks, will receive federal protection against invasion by any undesirable activity. These regions are, in part at least, of the bare granite type at high altitude. A careful study and exploration of these regions from Yuba River southward to the Merced River has led to the selection of watersheds on the headwaters of the Tuolumne River as the most desirable producing ground for water for San Francisco. Some of the facts that compel this conclusion may be briefly reviewed. Not one of the Sierra Nevada rivers, except Feather River, has a summer flow which would be adequate to meet the requirements of San Francisco in the matter of sufficiency of supply. But Feather River is out of consideration by reason of the remoteness of this source, the disadvantage of a conduit route that would cross the straits of Carquinez and the Bay of San Francisco, and the unfavorable collecting ground of the water, the vast extent and accessibility of which would render it impossible to exclude human habitations.

Water storage may, therefore, be set down as a requisite feature of any Sierra Nevada water project.

This having been determined, it is natural that the first thought should be of Lake Tahoe as an ideal source of water. No fault can be found with the quality of the water in the lake, which has a surface area of 250 sq. miles and is fed by the run-off from 250 sq. miles of high surrounding mountains. The mean annual outflow from the lake, through Truckee River, is equal to a layer of water 17 in. deep over the lake surface. This would be adequate for a population of about 2 000 000 people. Moreover, this water production could be increased somewhat by adding the water of Rubicon Creek, making an interconnection between a small reservoir on Rubicon Creek and the lake by tunnel, in which water would flow into or out of the lake according to whether the creek were producing more or less water than conduit capacity to the city. But there are riparian rights around Lake Tahoe and improved properties on the lake shore, there are acquired rights to the flow of Truckee River for various purposes, and, moreover, full use is to be made of the entire stream flow in Nevada for irrigation. The superior use of the water for a municipal supply might be difficult to establish, particularly as the lake, and the watershed tributary to the lake, lie in two states and the flow from the lake is into the neighboring state, Nevada. So long as other adequate sources of supply in the Sierra Nevada are available, Lake Tahoe may, therefore, be dismissed from consideration.

Yuba River has received due consideration in the water supply investigation, more perhaps, than this river deserved. The same objection to location applies as in the case of Feather River. The water would be under suspicion of contamination and should be filtered before use. As in the case of a Feather River project, the crossing of the Bay of San Francisco is a feature that weighs heavily against the project.

American River comes under consideration on the same basis as the remaining Sierra Nevada streams. Its low water flow is already appropriated and in use for various purposes. Water to be made available on this stream must be impounded in reservoirs. Sites for large reservoirs, located so that they can be filled, have not been found in the high mountains. Long conduits of large capacity to low mountain basins, where local undesirable run-off complicates the problem, become features of the various American River projects. The high mountain area that belongs in the class that can be permanently preserved in an uninhabited condition is relatively small. This river, therefore, is less attractive than the Tuolumne, to which these objections relating to storage facilities and protection of watersheds do not apply.

Cosumnes River has, properly speaking, no high mountain watersheds.

Mokelumne River, under coöperation of water power companies, which control the situation, can be made available, but storage will be scattered in a large number of relatively small reservoirs and there will be much human activity in some of the areas tributary to the storage sites. It offers no such cleancut and attractive project as that outlined for the Tuolumne River.

On the Stanislaus River there are fair opportunities for storing water, but they are scattered and are, in part at least, already in use to supply water for power and other useful purposes. There is no place known on this stream where there is any approximation to the advantages offered by such a site as Hetch Hetchy Valley on the Tuolumne River.

In the case of Tuolumne River, as has been pointed out, exceptional facilities exist for storing water. Two sites were selected for the city of San Francisco. Both of these, and the tributary watersheds, are within a national forest reservation. Both are high enough in the mountains to exclude from tributary watersheds the undesirable lower lying mountain slopes. Their combined storage capacity, as originally planned, is about 45 000 000 000 gal. of water. This can be doubled by making

the dams higher. Where the river below these dams will carry the water to a point of diversion, the river lies in a deep cañon and its accessions are from small timbered mountain areas. Should it ever become desirable to exclude parts of these watersheds below the main reservoirs, this can be done by extending the headworks farther upstream. The fact that the divide between the main fork of the Tuolumne and the South Fork above the selected point of diversion lies very close to the main stream is a favorable feature; there will probably never be any south side run-off, except local hillside waters, to be excluded. On the north side of the main stream, Cherry Creek drains a region which is throughout acceptable as a tributary watershed. The only other stream of note coming in from the north is Jawbone Creek, on which, in the course of time, lumber interests may concentrate sufficient population, for a time at least, to make its exclusion desirable. A short extension of the canal upstream (about 1½ miles) would accomplish this.

The route for a conduit to bring the water from Tuolumne River to San Francisco is practicable and has, as stated, been surveyed. It includes a very long pipe line, but this, as is well known, is a necessary feature of any project for a water supply from the Sierra Nevada.

San Francisco has now advanced to the point where she controls storage sites in which abundant storm water from high mountain watersheds may be impounded to meet the needs of the growing city for many years. The secured source of supply can be used to supplement the Spring Valley system, or the water can be brought to the city in independent water works.

The city must now determine whether to adopt any or none of the following methods of procedure:

1. Continue as at present, water to be supplied by the Spring Valley Water Company at a fair compensation, and the works to be expanded to other sources as the needs of the city demand.

2. Construct an independent system of works with the Tuolumne River as a source of supply.

3. Acquire by purchase the established water works and add thereto, as a first enlargement, water from Tuolumne River.

The disadvantages of the first course of action have been made plain by experience. It will continue to involve the city in an annual wrangle with the water company concerning rates. The water company will, as in the past, find it difficult to extend its works as rapidly as good judgment would indicate

to be desirable. The probability will be that other near-at-hand sources of supply will be added before the works will be extended to any Sierra Nevada source.

If the city constructs a municipal system of water works as an opposition plant to the established works, the outcome will be that the value of most of the properties of the Spring Valley Water Company will be destroyed. This is particularly true of such portions of the works as cannot be used for other purposes than the supply of water to San Francisco. Operation by the company in opposition to the municipality is entirely out of the question. The rate payers will quickly learn that what they do not pay to the city in water rates must be paid in taxes. The private company could not name rates low enough to hold consumers, particularly when quality of water is considered. But the construction of a system entirely apart from the old has its disadvantages. The pipe system in the city streets would have to be duplicated, and some 50 000 house connections would have to be made at large expense to the property owners. The construction of a new system of pipes extending along every street would do no small injury to street pavements. Should the company desire to save any pipe by removal from the ground this might mean a duplication of much of the trenching. There would not be as much nearby storage as desirable.

Now that the city is ready to move in the matter of acquiring a system of water works, the only one of the three courses above enumerated that seems advisable lies along lines indicated in No. 3. The city needs certain things which the Spring Valley Water Company has, and it needs some of them most decidedly.

The city needs the distributing system of the water company, pumps, reservoirs, tanks and pipes without reservation. The city needs the peninsula storage system, Pilarcitos, San Andres and Crystal Springs reservoirs and watersheds. The city needs the pipe lines from these reservoirs to the city and the receiving reservoirs. The city needs Lake Merced as an emergency source of water, and it needs the Merced lands for park purposes. The city needs all of the properties of the water company, particularly if it should be found desirable to unite with other municipalities in the control of all nearby sources of water, and in the addition of a supply from the Sierra Nevada.

The city, if it become the owner of the water company properties, can continue the operation of the water works and

make suitable provision for the increasing demand for water during the time the Sierra Nevada works are under construction.

If the city, on the other hand, enters upon the construction of independent water works, it must be expected that the Spring Valley Water Company will curtail expenditures as much as possible, refraining particularly from new construction, and as a result there may be some years before the new works come into service in which the water supply will prove deficient.

In case that the course, which has been pointed out to be the natural one, be followed, the first step to be taken will be to reach an agreement with the Spring Valley Water Company concerning the price at which its properties will be sold to the city. It will then be possible to outline a water supply project based upon the works as now in service, supplemented by a water supply of prime quality from the Tuolumne River, developed at the points where the city has already acquired rights of storage.

Again quoting from the writer's report on available sources of water, dated November 24, 1902:

"Expense, so long as the same is within reason and not a burden upon the community, should not be spared in obtaining the best water that may be had."

There should be no hesitation, first, in acquiring the present water works, if this may be done at a fair price, and second, in reaching out to Hetch Hetchy Valley and Lake Eleanor for an additional supply.

[NOTE. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 15, 1908, for publication in a subsequent number of the JOURNAL.]